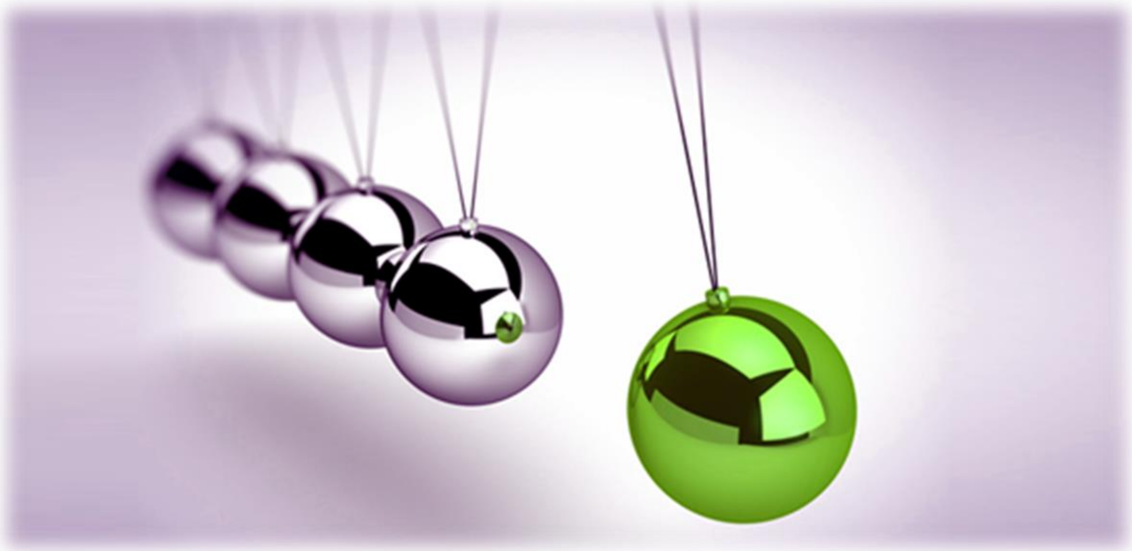
PHYSICS
MECHANICS



Doç. Dr. Ahmet KARATAY
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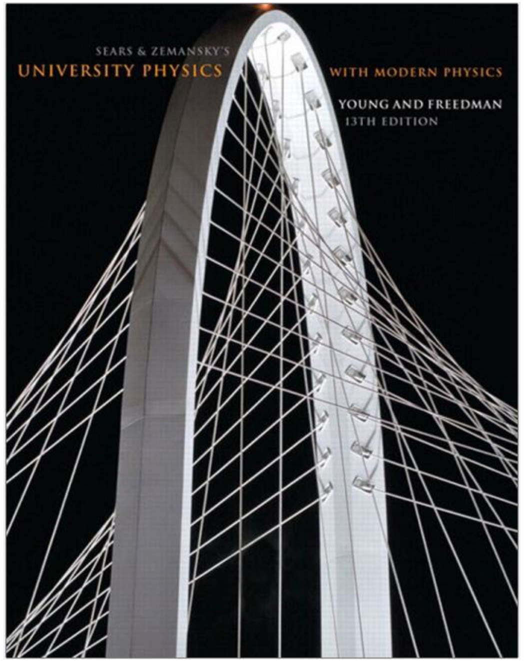
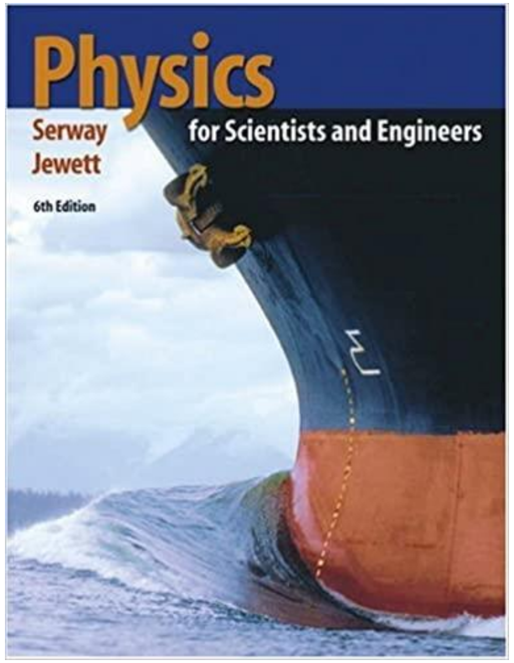
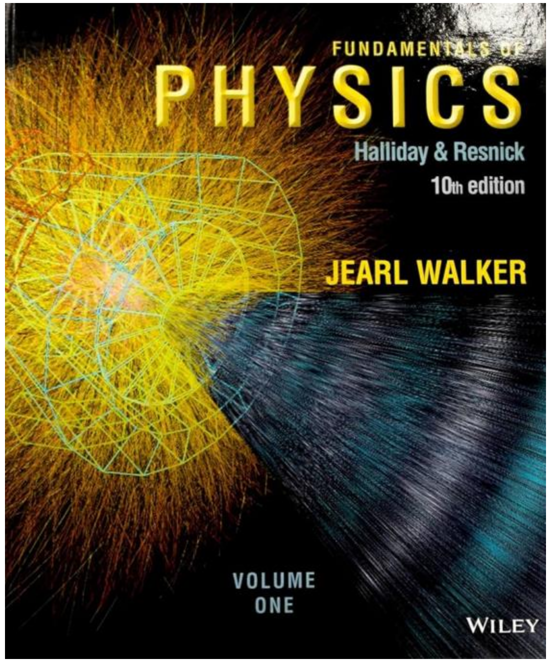
Source Books



Sears and Zemansky's University Physics with Modern Physics
Young and Freedman



Physics For Scientists And Engineers
Serway and Beichner



Fundamentals of Physics 1
(Resnick, Halliday, Walker)

Physics-I Mechanics– Goal of the Course

The objective of this course:

- ✓ To provide a foundation in the branch of physics concerned with mechanics necessary for further study in science, engineering and technology.
- ✓ To provide an understanding of the nature of mechanics, its methods and its goals.
- ✓ To contribute the development of the student's thinking process through the understanding of the theory and application of this knowledge to the solution of the practical problems.

Physics-I Mechanics– Course Plan

Credit:	3 ECTS
Class:	Lecture: 3 hours
Class Hours:	Wednesday 12:30-15:30

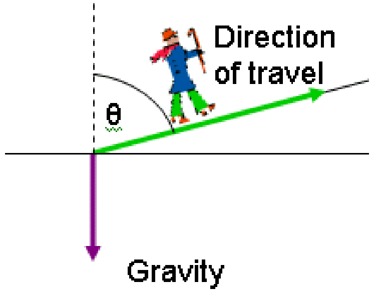
Exams

Midterm: 40 % Final Exam: 60%

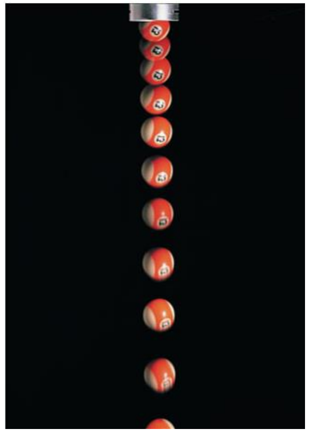
Passing Grade: 60 (C3) or higher

Physics-I Mechanics– Content of the Course

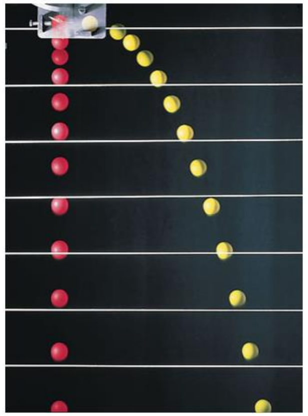
1. Physics and measurements



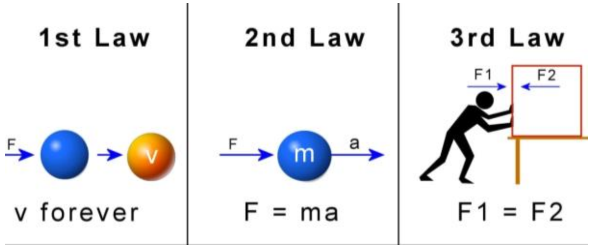
2. Vectors



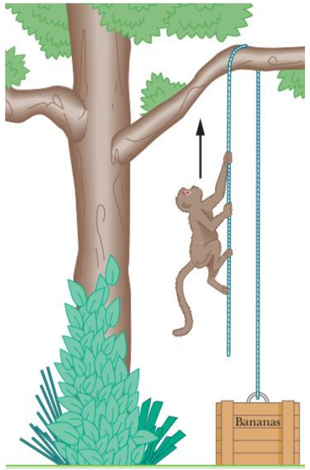
3. Motion in One Dimension



4. Two dimensional motion

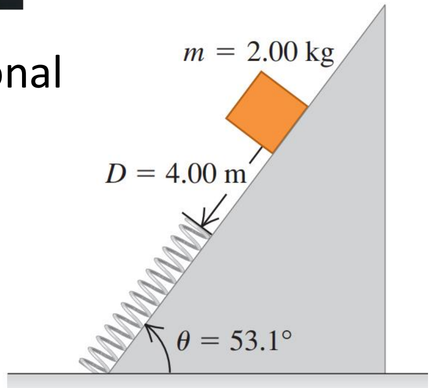


5. The Laws of Motion

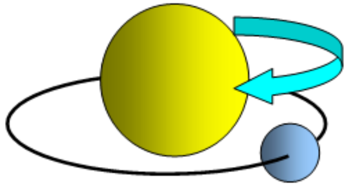


6. Some Applications of Newton's Laws

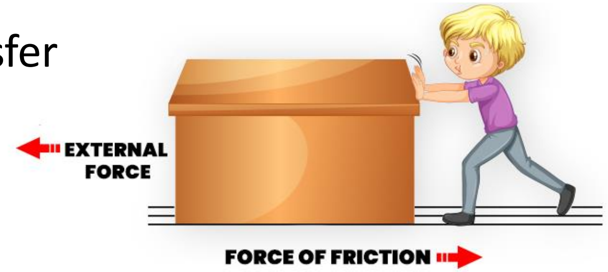
8. Energy and Energy Transfer



10. Potential Energy



7. Circular Motion



9. Situations Involving Kinetic Friction and Power

11. Relationship Between Conservative Forces and Potential Energy

CHAPTER 1- Physics and Measurements

1.1 Standards of Length, Mass and Time

1.2 Matter and Model Building

1.3 Density and Atomic Mass

1.4 Dimensional Analysis

1.5 Conversion of Units

1.6 Estimates and Order-of Magnitude Calculations

1.7 Significant Figures

What is Physics?

Physics, the most fundamental physical science, is concerned with the basic principles of the Universe.

Physics studies matter, its motion and behavior through space and time, and the related entities of energy and force.

The study of physics involves the investigation of such things as

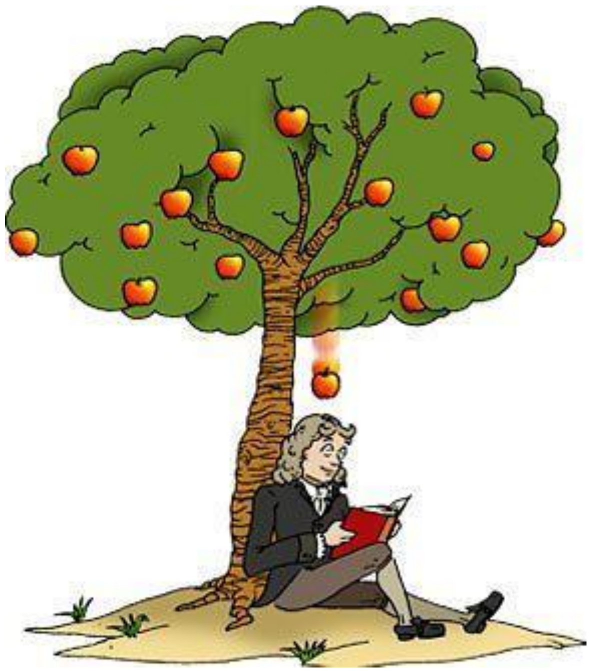
The law of motion

The structure of space and time

The nature and type of forces that hold different materials together

The interaction between different particles

The interaction of electromagnetic radiation with matter and so on



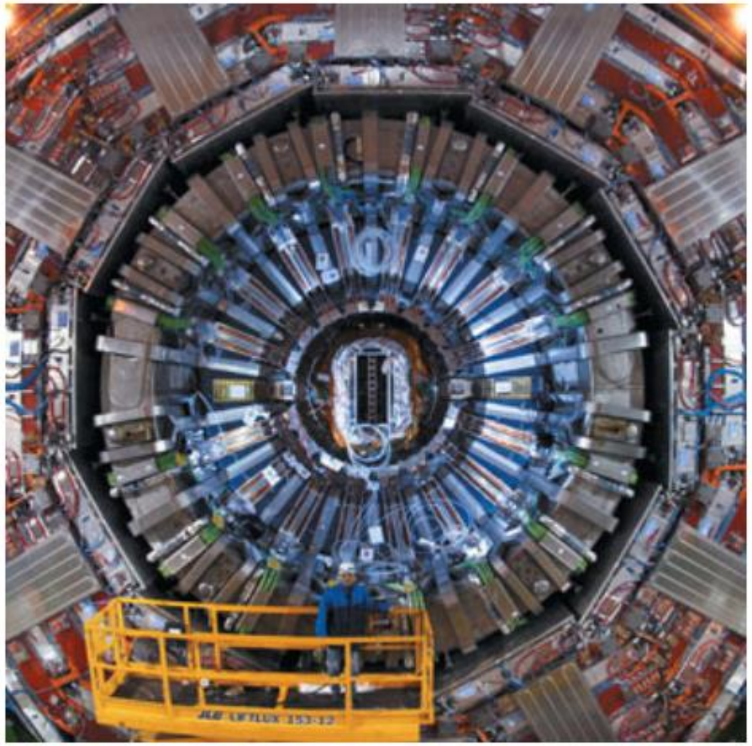
The study of physics can be divided into six main areas:

1. Classical Mechanics
2. Relativity
3. Thermodynamics
4. Electromagnetism
5. Optics
6. Quantum Mechanics

What is Physics?

(a)

(b)



(a) According to legend, Galileo investigated falling bodies by dropping them from the Leaning Tower in Pisa, Italy.

(b) The Large Hadron Collider (LHC) in Geneva, Switzerland, the world's largest particle accelerator.

1.1 Standards of Length, Mass and Time

The laws of physics are expressed as mathematical relationships among physical quantities.

The value of a physical quantity is actually the product of a number and an unit.

How high is the apple?   **How about its mass?**

Height: 6 cm = 0.06 m

Mass: 300 gr = 0.3 kg

Number   **Unit**

"Thickness is 10." does not have any physical meaning. Both numbers and units needed to any significant physical quantity.

1.1 Standards of Length, Mass and Time

Most of these quantities are *derived quantities,* in that they can be expressed as combinations of a small number of *basic quantities*.

Length [L]

Mass [M]

Time [T]

In 1960, an international committee established a set of standards for the fundamental quantities of science. It is called the SI (Système International).

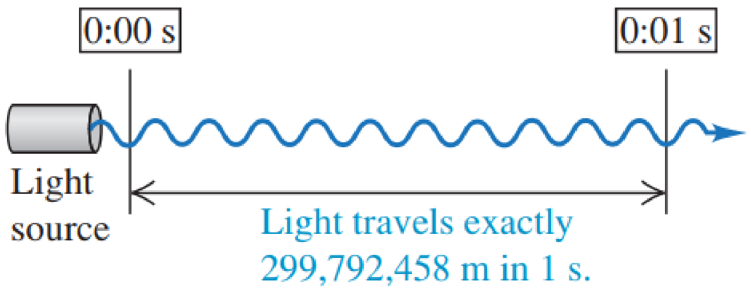
Quantity	Unit Name	Unit Symbol
Length	meter	m
Time	second	s
Mass	kilogram	kg

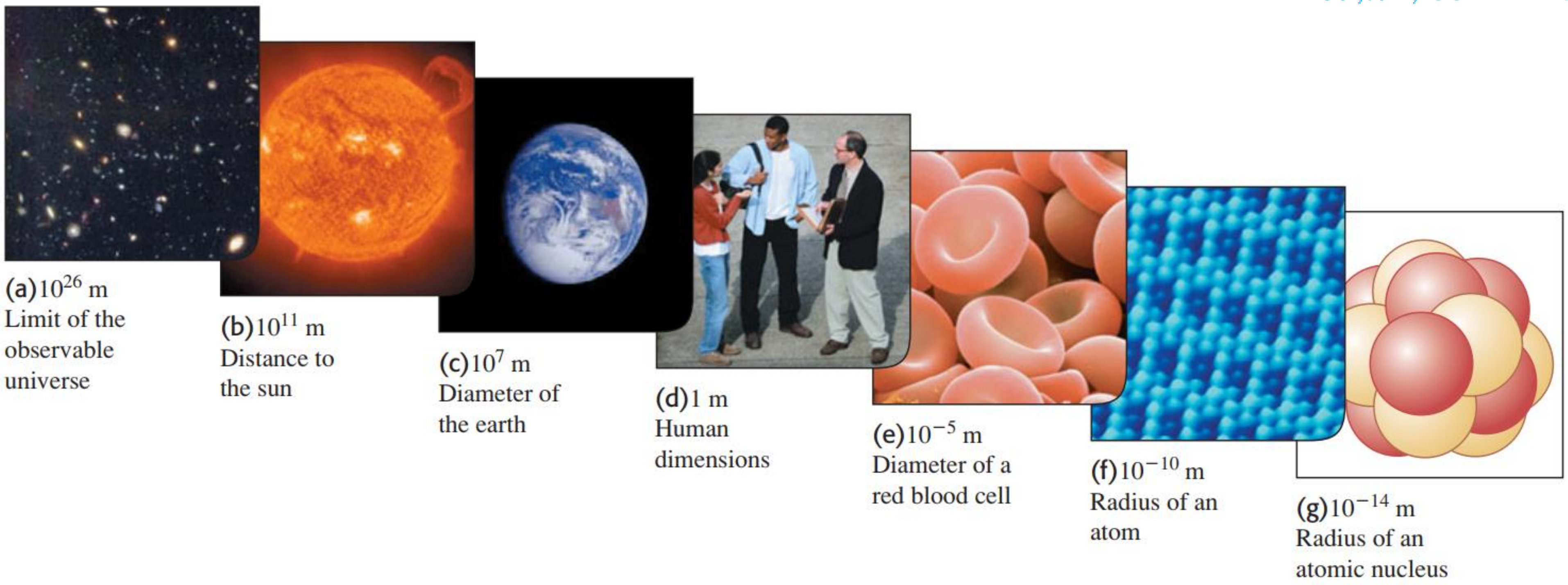
Temperature (Kelvin), electric current (Amapere), luminous intensity (candela), amount of substance (mole)

1.1 Standards of Length, Mass and Time

Length

- Defined in terms of a meter – the distance traveled by light in a vacuum during a given time
- Units
  - SI (Système International) meter, m
  - cgs – centimeter, cm
  - US Customary – foot, ft



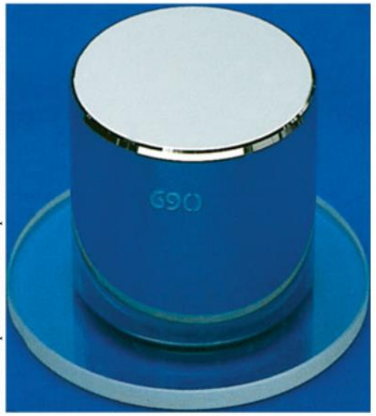


1.1 Standards of Length, Mass and Time

Mass

- Defined in terms of kilogram, based on a specific platinum-iridium alloy cylinder kept at the International Bureau of Weights and Measures at Sèvres, France.
- Units
  - SI – kilogram, kg
  - cgs – gram, g
  - USC – slug, slug

Object	Mass in Kilograms
Known universe	1×10^{53}
Our galaxy	2×10^{41}
Sun	2×10^{30}
Moon	7×10^{22}
Asteroid Eros	5×10^{15}
Small mountain	1×10^{12}
Ocean liner	7×10^{7}
Elephant	5×10^{3}
Grape	3×10^{-3}
Speck of dust	7×10^{-10}
Penicillin molecule	5×10^{-17}
Uranium atom	4×10^{-25}
Proton	2×10^{-27}
Electron	9×10^{-31}

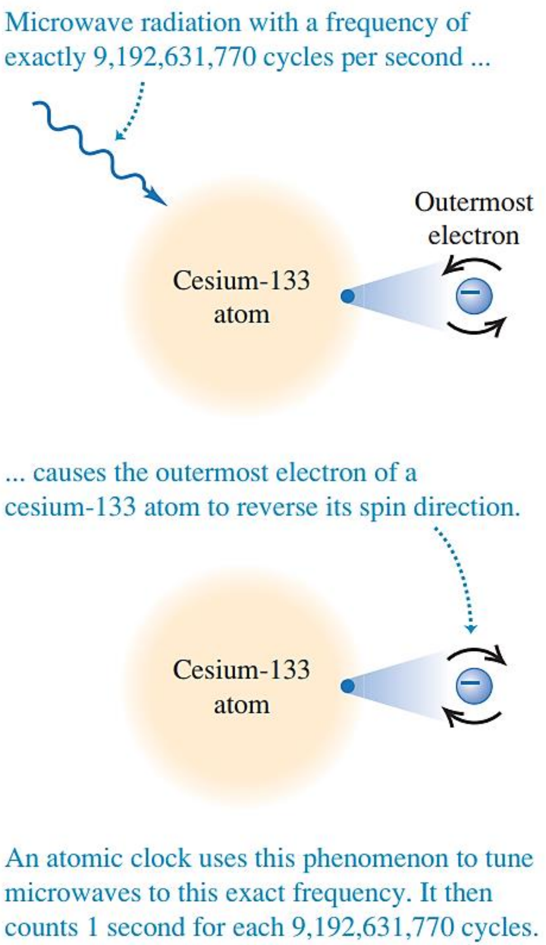


The international 1 kg standard of mass, a platinum–iridium cylinder 3.9 cm in height and in diameter

1.1 Standards of Length, Mass and Time

Time

- Defined in terms of the oscillation of radiation from a cesium atom
- Units
  - seconds, s in all three systems



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}

[a]This is the earliest time after the big bang at which the laws of physics as we know them can be applied.

1.1 Standards of Length, Mass and Time

Prefixes

- Prefixes correspond to powers of 10
- Each prefix has a specific name
- Each prefix has a specific abbreviation

İMPORTANT

Multiples and Submultiples Prefixes Tables

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

Length

1 nanometer $= 1$ nm $= 10^{-9}$ m
(a few times the size of the largest atom)

1 micrometer $= 1\ \mu$m $= 10^{-6}$ m
(size of some bacteria and living cells)

1 millimeter $= 1$ mm $= 10^{-3}$ m
(diameter of the point of a ballpoint pen)

1 centimeter $= 1$ cm $= 10^{-2}$ m
(diameter of your little finger)

1 kilometer $= 1$ km $= 10^{3}$ m
(a 10-minute walk)

Mass

1 microgram $= 1\ \mu$g $= 10^{-6}$ g $= 10^{-9}$ kg
(mass of a very small dust particle)

1 milligram $= 1$ mg $= 10^{-3}$ g $= 10^{-6}$ kg
(mass of a grain of salt)

1 gram $= 1$ g $= 10^{-3}$ kg
(mass of a paper clip)

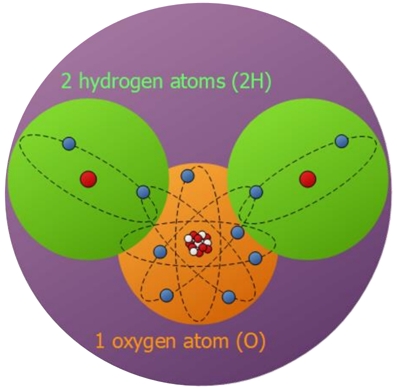
Time

1 nanosecond $= 1$ ns $= 10^{-9}$ s
(time for light to travel 0.3 m)

1 microsecond $= 1\ \mu$s $= 10^{-6}$ s
(time for space station to move 8 mm)

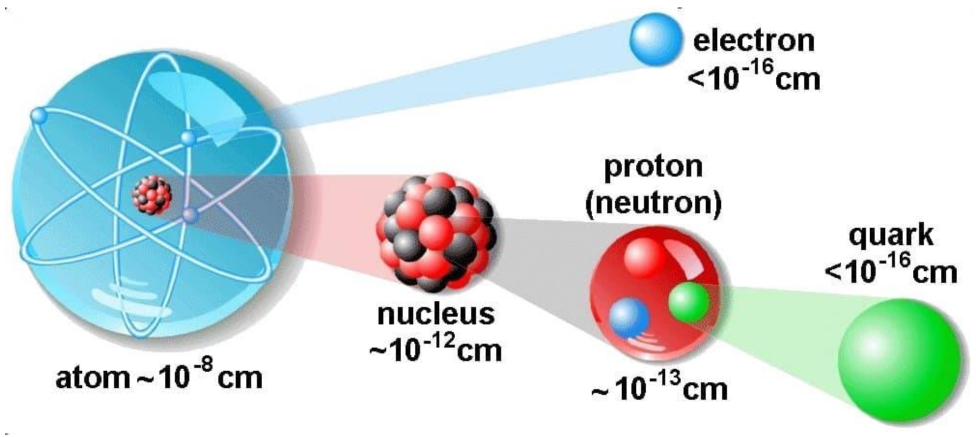
1 millisecond $= 1$ ms $= 10^{-3}$ s
(time for sound to travel 0.35 m)

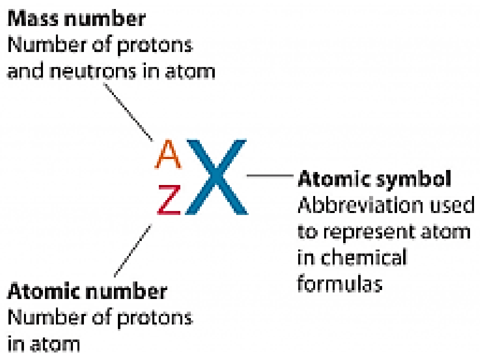
1.2 Matter and Model Building

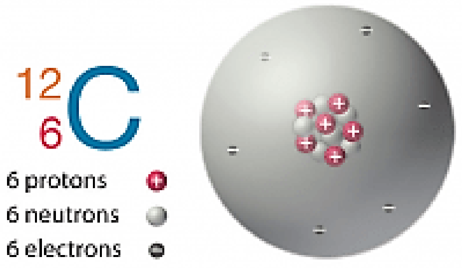


- Matter is made up of molecules
  - the smallest division that is identifiable as a substance
- Molecules are made up of atoms
  - correspond to elements

- Atoms are made up of
  - nucleus, very dense, contains
    - protons, positively charged, “heavy”
    - neutrons, no charge, about same mass as protons
      - protons and neutrons are made up of quarks
  - orbited by
    - electrons, negatively charged, low mass (compared to proton)
      - fundamental particle, no structure







1.3 Density and Atomic Mass

The density ρ (Greek letter rho) of any substance is defined as its *mass per unit volume:*

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

Aluminum has a density of 2.70 g/cm^3 a piece of aluminum of volume 10.0 cm^3 has a mass of 27.0 g

Lead has a density of 11.3 g/cm^3 a piece of lead of volume 10.0 cm^3 has a mass of 113 g

mass of a single atom of the element measured in atomic mass units (u)

Atomic mass units (u) 1 u=1.660 538 7 x 10^{-27} kg

Quick Question!

In a machine shop, two cams are produced, one of aluminum and one of iron. Both cams have the same mass. Which cam is larger? (ρ_{Al}= 2.70 g/cm^3 ρ_{Fe}= 7.847 g/cm^3)

(a) The aluminum cam (b) the iron cam (c) Both cams have the same size.

1.3 Density and Atomic Mass

Example:

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 x 10^{23} atoms. How many aluminum atoms are contained in the cube?

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

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

$$\begin{aligned} m_{\text{sample}} &= kN_{\text{sample}} \\ m_{27.0\ \mathrm{g}} &= kN_{27.0\ \mathrm{g}} \end{aligned} \quad \longrightarrow \quad \frac{m_{\text{sample}}}{m_{27.0\ \mathrm{g}}} = \frac{N_{\text{sample}}}{N_{27.0\ \mathrm{g}}}$$

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

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

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

1.4 Dimensional Analysis

The word *dimension* denotes the physical nature of a quantity. Dimensions are often denoted with square brackets. It is a technique to check the correctness of an equation or to assist in deriving an equation.

Length [L]

Mass [M]

Time [T]

Speed v [*v*] = L/T

Area A [*A*] = L^2

System	Area (L^2)	Volume (L^3)	Speed (L/T)	Acceleration (L/T^2)
SI	m^2	m^3	m/s	m/s^2
U.S. customary	ft^2	ft^3	ft/s	ft/s^2

Analyzing of Dimension

- ✓ Dimensions (length, mass, time, combinations) can be treated as algebraic quantities.
- ✓ Both sides of equation must have the same dimensions.
- ✓ Any relationship can be correct only if the dimensions on both sides of the equation are the same.
- ✓ Cannot give numerical factors: this is its limitation

1.4 Dimensional Analysis

Example:

Determine the dimensions and SI units of the following physical quantities:

- Force
- Pressure
- Work
- Potential Energy
- Power

$$[F] = [m][a] = M\ L\ T^{-2}$$

$$[P] = \left[\frac{F}{A}\right] = \frac{M\ L\ T^{-2}}{L^2} = M\ L^{-1}\ T^{-2}$$

$$[W] = [F][x] = M\ L\ T^{-2} L = M\ L^2\ T^{-2}$$

$$[P.E.] = [m][g][h] = M\ L\ T^{-2} L = M\ L^2\ T^{-2}$$

$$[Power] = \left[\frac{W}{t}\right] = \frac{M\ L^2\ T^{-2}}{T} = M\ L^2\ T^{-3}$$

1.4 Dimensional Analysis

True or False

[L] = length [M] = mass [T] = time

Is the following equation dimensionally correct?

$$x = \tfrac{1}{2} v t^2$$

$$[\mathrm{L}] = \left[\frac{\mathrm{L}}{\mathrm{T}}\right][\mathrm{T}]^2 = [\mathrm{L}][\mathrm{T}]$$

Is the following equation dimensionally correct?

$$x = vt$$

$$[\mathrm{L}] = \left[\frac{\mathrm{L}}{\mathrm{T}}\right][\mathrm{T}] = [\mathrm{L}]$$

1.5 Conversion of Units

To convert between units:

- Figure out what CONVERSION FACTOR you need to perform your calculation

$$\cancel{\text{Given unit}} \times \frac{\text{desired unit}}{\cancel{\text{given unit}}} = \text{desired unit}$$

Conversion factors – take a definition and turn it into a fraction equal to one

$$1\ \text{hr} = 60\ \text{min} \qquad \frac{1\ \text{hr}}{60\ \text{min}} \quad \text{or} \quad \frac{60\ \text{min}}{1\ \text{hr}}$$

- When units are not consistent, you may need to convert to appropriate ones
- Units can be treated like algebraic quantities that can "cancel" each other

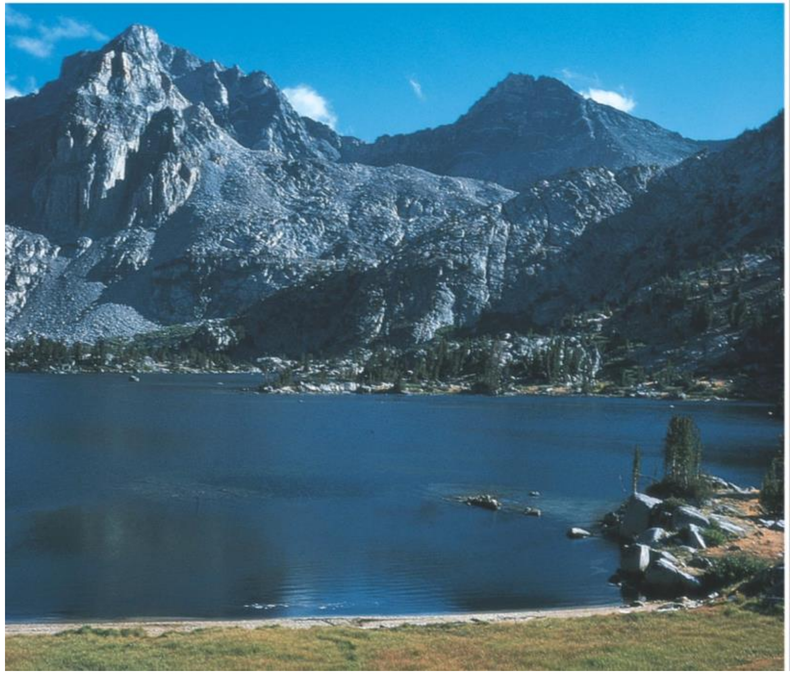
Example: Which fractions would you need to use to figure out how many seconds are in 7.4 hr?

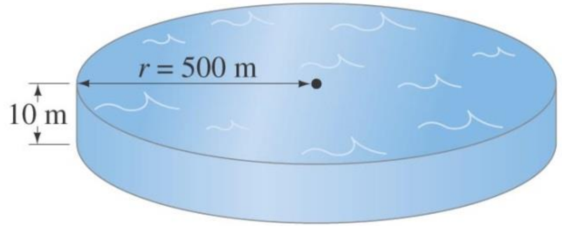
7.4 ~~hr~~	60 ~~min~~	60 s	26640 s
	1 ~~hr~~	1 ~~min~~	

1.6 Estimates and Order-of Magnitude Calculations

A quick way to estimate a calculated quantity is to round off all numbers to one significant figure and then calculate. Your result should at least be the right order of magnitude; this can be expressed by rounding it off to the nearest power of 10.

Example: **Rapid Estimating of Volume of a lake.**





Estimate how much water there is in a particular lake, which is roughly circular, about 1 km across, and you guess it has an average depth of about 10 m.

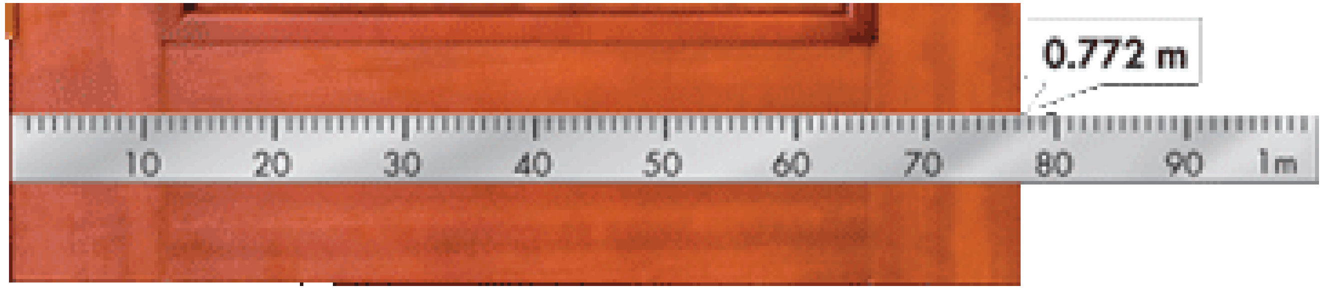
$$V = h \ x \ (\pi r^2) = 10m \ x \ (\pi \ (500m)^2)$$

V= 7 850 000 $m^3 = 7.85 \ x \ 10^6 \ \ m^3$

1.6 Significant Figures ANLAMLI RAKAMLAR

The measured values are known only to within the limits of the experimental uncertainty

- The quality of the apparatus
- The skill of the experimenter
- Number of the measurements that are performed



!!! Significant figures in a measurement include

- ✓ all of the digits that are known precisely
- ✓ plus one last digit that is estimated

1.6 Significant Figures

Rules for significant figures

1. Non-zero digits are always significant.

24.7 meters
0.**743 meter**
714 meters

2. Zeros appearing between nonzero digits are significant.

7**00**3 **meters**
4**0**.79 **meters**
1.5**0**3 **meters**

3. Trailing zeros follow a non zero digit and are significant only if there is a decimal point.

0.005**00**

2.3**0** x 10^{-5}

1**00.000**

4.5**00** x 10^{12}

0.03**0**4**0**

4. Zeros used only for spacing the decimal point are not significant

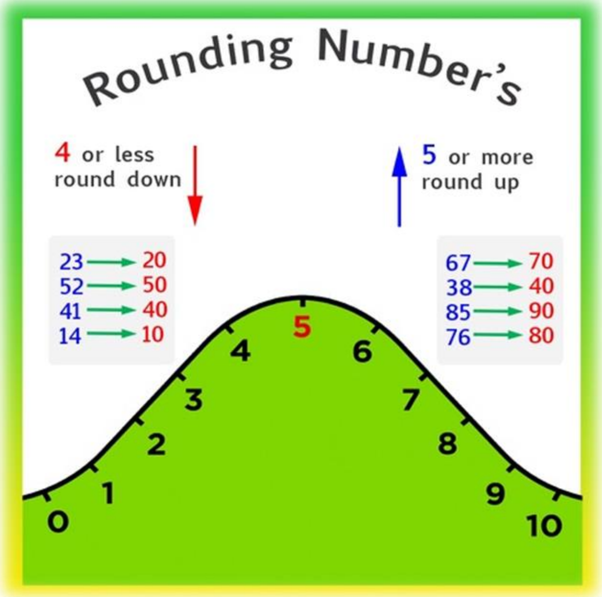
100
0.00000566

1.6 Significant Figures

Significant Figures in Calculations

Rounding

- To round a number, first decide how many significant figures the answer should have.
- Then round to that many digits, counting from the left.
- “4 & below, round down”
- “5 & above, round up”



Example: Rounding Measurements

Round off each measurement to the number of significant figures shown in parentheses.

a. 314.721 meters (four) 314.7

b. 0.001 775 meter (two) 0.0018

c. 8792 meters (two) 8800

1.6 Significant Figures

Significant Figures in Calculations

If you multiply or divide two numbers, the answer is rounded off to the number of significant figures in the least precise term used in the calculation (i.e. The number with the fewest significant figure).

Multiplication or division:
Result may have no more significant figures than the starting number with the fewest significant figures:

$$\frac{0.745 \times 2.2}{3.885} = 0.42$$

$$1.32578 \times 10^7 \times 4.11 \times 10^{-3} = 5.45 \times 10^4$$

Give the answers to the correct number of significant figures.

a. 7.55 meters x 0.34 meter

b. 2.10 meters x 0.70 meter

c. 2.4526 meters^2 ÷ 8.4 meters

1.6 Significant Figures

Significant Figures in Calculations

a) 7.55 meters x 0.34 meter

The second measurement (0.34 meter) has the least number of significant figures (two). So, the answer must be rounded to two significant figures.

$$7.55 \text{ meters} \times 0.34 \text{ meter} = 2.567 \text{ meters}^2$$

$$\mathbf{= 2.6 \text{ meters}^2}$$

b) The second measurement (0.70 meter) has the least number of significant figures (two). So, the answer must be rounded to two significant figures.

$$2.10 \text{ meters} \times 0.70 \text{ meter} = 1.47 \text{ meters}^2$$

$$\mathbf{= 1.5 \text{ meters}^2}$$

c) The second measurement (8.4 meters^2) has the least number of significant figures (two). So, the answer must be rounded to two significant figures.

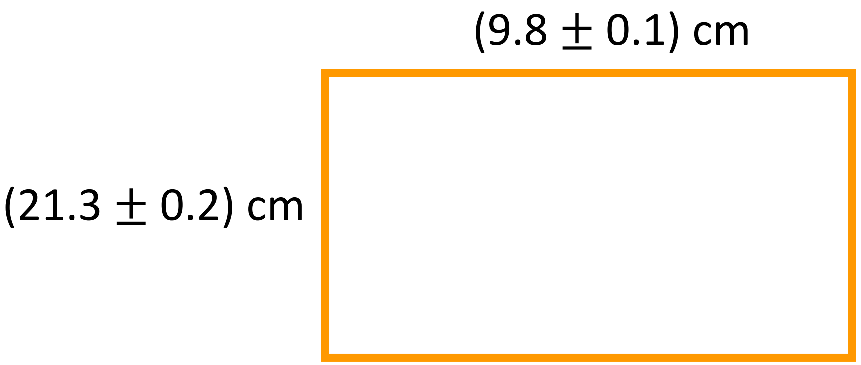
$$2.4526 \text{ meters}^2 \div 8.4 \text{ meters} = 0.291\,076 \text{ meter}$$

$$\mathbf{= 0.29 \text{ meter}}$$

1.6 Significant Figures

Significant Figures in Calculations

A rectangular plate has a length of (21.3 ± 0.2) cm and a width of (9.8 ± 0.1) cm. Calculate the area of the plate, including its uncertainty.



METHOD ONE

We treat the best value with its uncertainty as a binomial $(21.3 \pm 0.2)\ \text{cm}\ (9.8 \pm 0.1)\ \text{cm}$,

$$A = \left[21.3(9.8) \pm 21.3(0.1) \pm 0.2(9.8) \pm (0.2)(0.1)\right]\ \text{cm}^2\ .$$

The first term gives the best value of the area. The cross terms add together to give the uncertainty and the fourth term is negligible.

$$A = \boxed{209\ \text{cm}^2 \pm 4\ \text{cm}^2}\ .$$

METHOD TWO

We add the fractional uncertainties in the data.

$$A = (21.3\ \text{cm})(9.8\ \text{cm}) \pm \left(\frac{0.2}{21.3} + \frac{0.1}{9.8}\right) = 209\ \text{cm}^2 \pm 2\% = 209\ \text{cm}^2 \pm 4\ \text{cm}^2$$

1.6 Significant Figures

Significant Figures in Calculations

If you add or subtract, the answer is rounded to the same number of decimal places as the measurement with the least number of decimal places.

Give the answer to the correct number of significant figures.

12.52 meters + 349.0 meters + 8.24 meters

12.52 meters
349.0 meters
+ 8.24 meters
369.76 meters

369.8 meters

Addition or subtraction:
Number of significant figures is determined by the starting number with the largest uncertainty (i.e., fewest digits to the right of the decimal point):

$$27.153 + 138.2 - 11.74 = 153.6$$

Find:	calculator result:	proper result:
1.2 cm + 2 cm	3.2 cm	3 cm
0.00530 m – 2.10 m	-2.0947 m	-2.09 m

1. Physics and Measurements

Homework

1- The standard kilogram is a platinum–iridium cylinder 39.0 mm in height and 39.0 mm in diameter. What is the density of the material?

2- Assuming that 70% of the Earth's surface is covered with water at an average depth of 3.7 km, estimate the mass of the water on the Earth in kilograms. (ρ_{water}= 1.00 g/cm^3)

3- How many significant figures are in the following numbers?

(a) 78.9 ± 0.2

(b) 3.788×10^9

(c) 2.46×10^{-6}

(d) 0.005 3

1- With $V = (\text{base area})(\text{height})$ $V = (\pi r^2)h$ and $\rho = \dfrac{m}{V}$, we have

$$\rho = \frac{m}{\pi r^2 h} = \frac{1\ \text{kg}}{\pi(19.5\ \text{mm})^2(39.0\ \text{mm})}\left(\frac{10^9\ \text{mm}^3}{1\ \text{m}^3}\right)$$

$$\rho = \boxed{2.15 \times 10^4\ \text{kg/m}^3}.$$

2- The area covered by water is

$$A_w = 0.70 A_{\text{Earth}} = (0.70)(4\pi R_{\text{Earth}}^2) = (0.70)(4\pi)(6.37 \times 10^6\ \text{m})^2 = 3.6 \times 10^{14}\ \text{m}^2.$$

The volume of the water is

$$V = A_w d = (3.6 \times 10^{14}\ \text{m}^2)(3.7 \times 10^3\ \text{m}) = 1.3 \times 10^{18}\ \text{m}^3$$

and the mass is

$$m = \rho V = (1\,000\ \text{kg/m}^3)(1.3 \times 10^{18}\ \text{m}^3) = \boxed{1.3 \times 10^{21}\ \text{kg}}.$$

3-
a) The ±0.2 following the 78.9 expresses uncertainty in the last digit. Therefore, there are three significant figures in **78.9** ± 0.2.
b) **3.788** X 10^9 four significant figures
c) **2.46** X 10^{-6} three significant figures
d) 0.00**53** two significant figures