DUT – RU International School
of Information Science & Engineering

College Physics

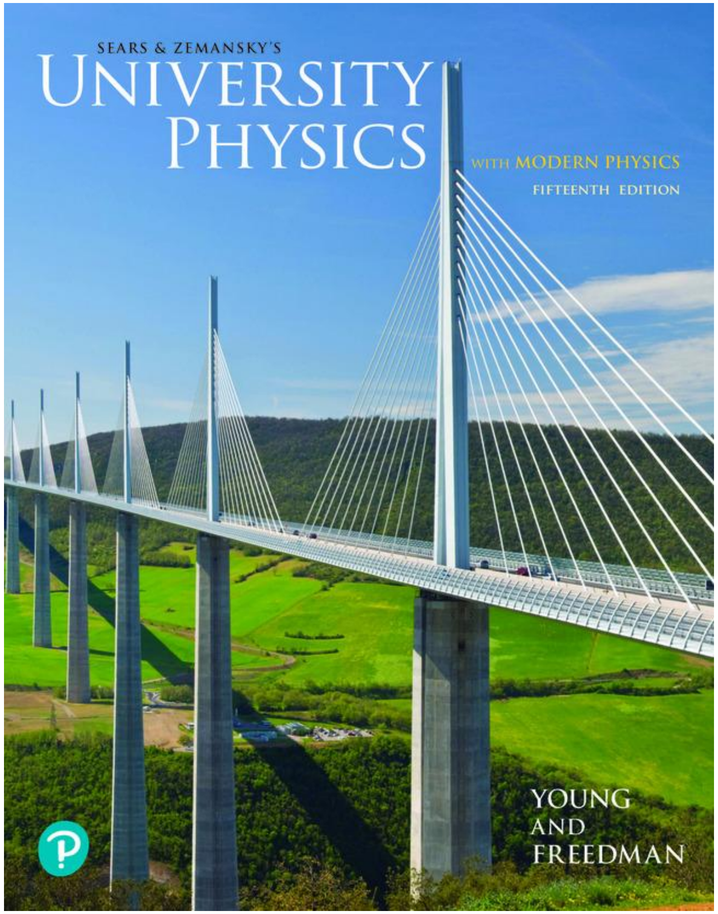
Dr. Aliaksandr Leonau

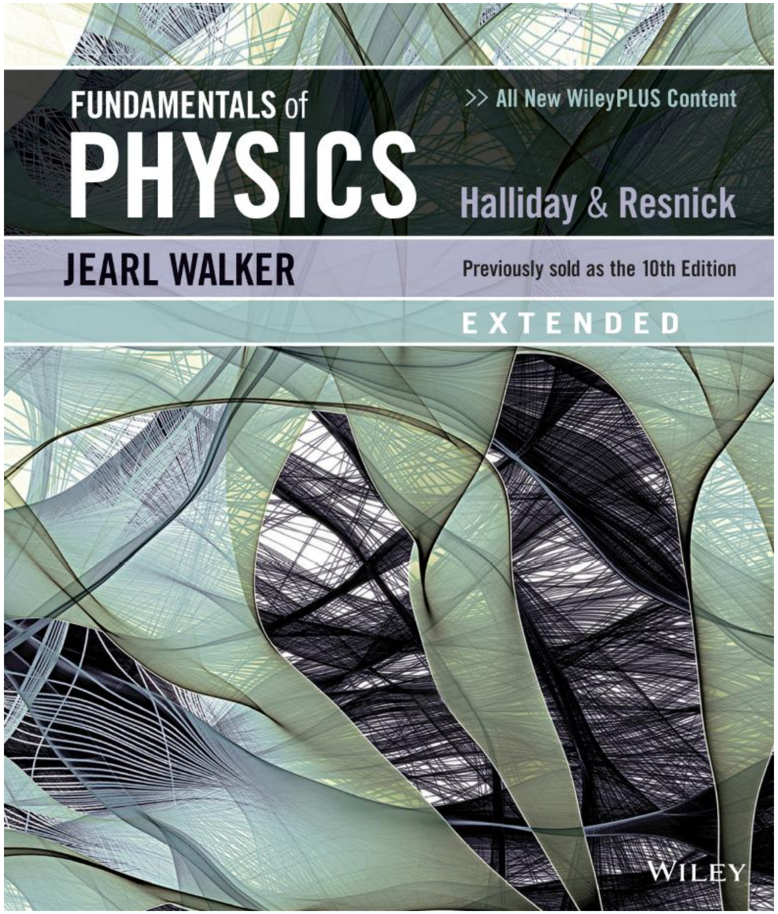
Lecture Course (online)
Dalian, 2022

Outline

- Introduction to Physics
- Mechanics
- Electricity and Magnetism
- Thermal Physics
- Vibrations and Waves
- Light and Optics
- Modern Physics

Textbooks

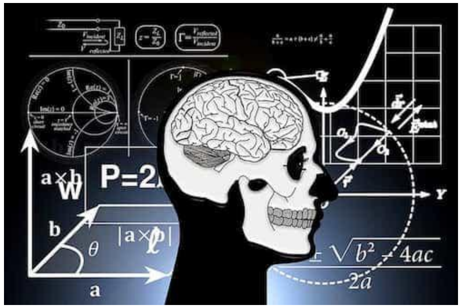




+ many other wonderful books on College and University Physics

Course Specifics

Physics is one of the most fundamental sciences. At the same time, it is very much a part of the world around us. In order to describe all related phenomena, physics needs a dedicated language. Such a language is provided by **mathematics**.



Course specifics:

- in order to understand the lectures clearly and (successfully) complete the course, **good knowledge** of fundamental mathematical concepts from algebra, geometry, trigonometry, and calculus **is required**
- this course gives a **brief** overview of some **selected topics**, which can provide you with basic understanding of the most important physical phenomena and methods of their description
- gaining new experience always requires **efforts** from your side: try to think over the new ideas, which you studied. Do NOT neglect homeworks and quizzes
- **participate** actively and **ask questions** (both during the online-class and later in the chat). If anything is unclear to you, do NOT postpone it for the future

Organizational Key Points

32 hours = 16 lectures

Lectures include:

- theoretical part
- self-quizzes
- solving problems

Evaluation and Grade:

- attendance (5 marks)
- checked homework (25 marks)
- final examination (70 marks)

Online Resources

QQ

For sharing the information (including the upload of electronic presentations) and making comments I will use our **group chat in QQ**.

Please, join it unless you have not done this earlier !

Please, type your ID and name in **Latin** using the following template:

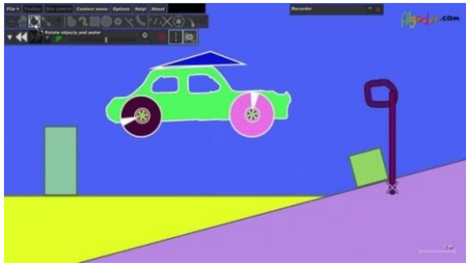
2021xxxxx-Surname,Name

private messages: QQ or via e-mail leonov.bsu@gmail.com

zoom

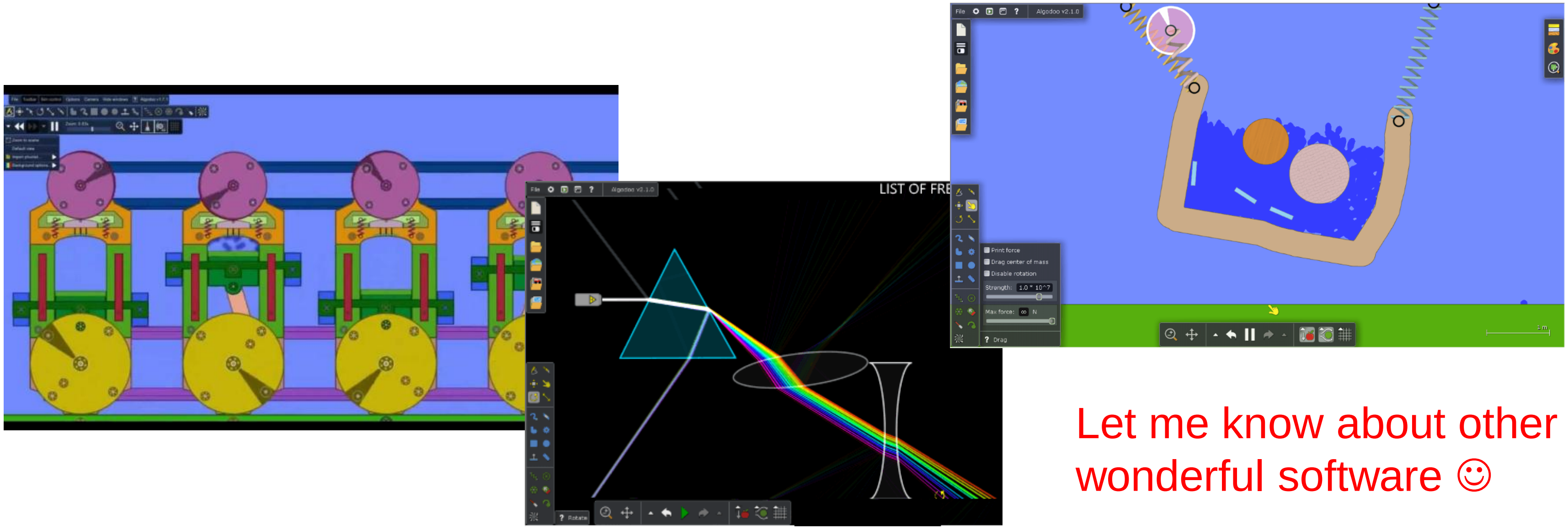
Our platform for the ONLINE lecture course

(Optional) For Curious Students



For better understanding of basic physical concepts and their visualization I can recommend to consider the free software of **Algodoo** (aka “play with physics”)

for downloading: **http://www.algodoo.com/download/**



Let me know about other wonderful software ☺

Topic # 1

Introduction to Physics

Lecture Course (online)
Dalian, 2022

Contents

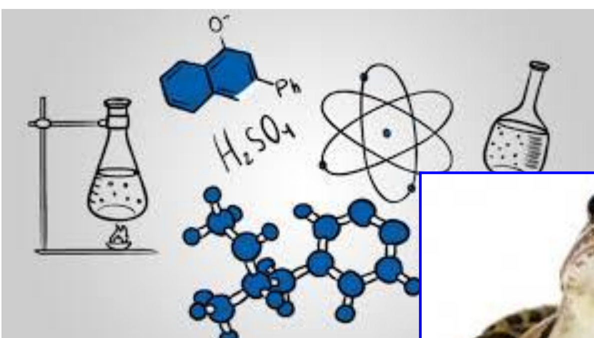
Why Study Physics ?

Physics is the branch of science that describes matter, energy, space, and time at the **most fundamental** level.

whatever your professional field is, some principles of physics are **relevant** to it anyway

The study of physics is valuable for several reasons:

all natural sciences are built on a foundation of the laws of physics



Chemistry

chemical physicists

Biology biophysicists

Geology

geophysicists

etc.

Astronomy astrophysicists

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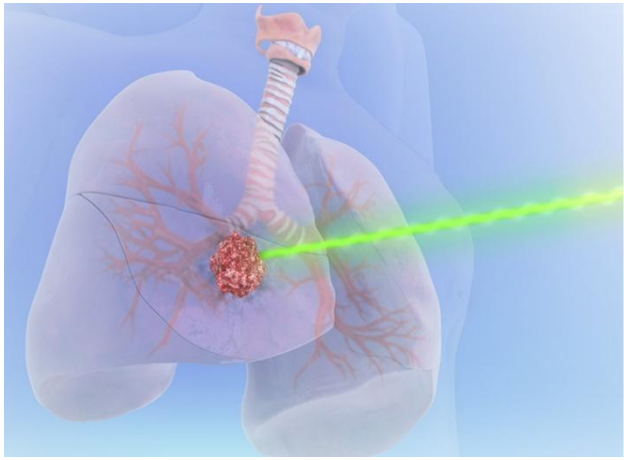
The study of physics is valuable for several reasons:

in today's technological world, many important devices can be understood correctly only with a knowledge of underlying physics



Radiation therapy

GPS

Heating up food

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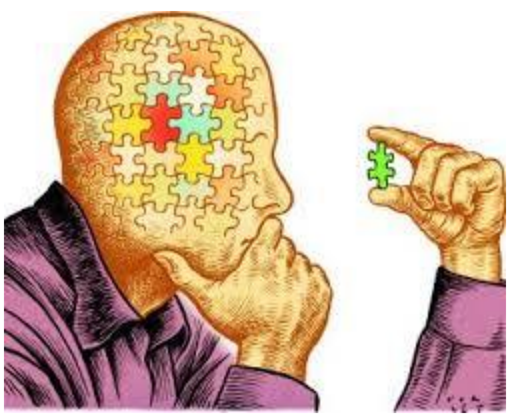
The study of physics is valuable for several reasons:

by studying physics, you acquire skills that are useful in other disciplines



Thinking logically and analytically

Solving problems

Constructing mathematical models

Making simplifying assumptions

Using valid approximations

Making precise definitions

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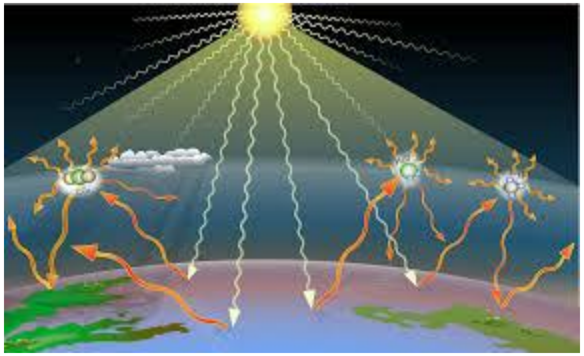
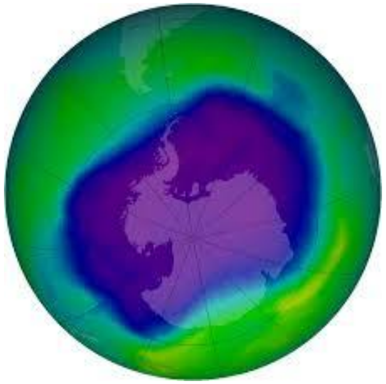
The study of physics is valuable for several reasons:

society's resources are limited, so it is important to use them in beneficial ways and not squander them on scientifically impossible projects

Safety of nuclear plants



Greenhouse effect



Ozone holes

Why Study Physics ?

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The study of physics is valuable for several reasons:

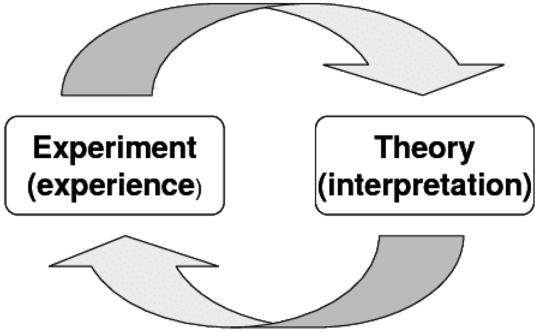
finally, by studying physics, you develop a sense of the beauty of the fundamental laws governing the universe

Theories and Experiments

Physics is an **experimental** science. Physicists observe the phenomena of nature and try to find patterns that relate these phenomena. These patterns are called **physical theories**.

The **goal** of physics is to provide an understanding of the physical world by developing **theories** based on **experiments**.

- a theory is a "guess", usually expressed mathematically, about how a given physical system works
- theory makes certain predictions about how a system should work
- experiments check the theories' predictions
- every theory is a work in progress



Note: every theory has a **range of validity**. No theory is ever regarded as the ultimate truth.

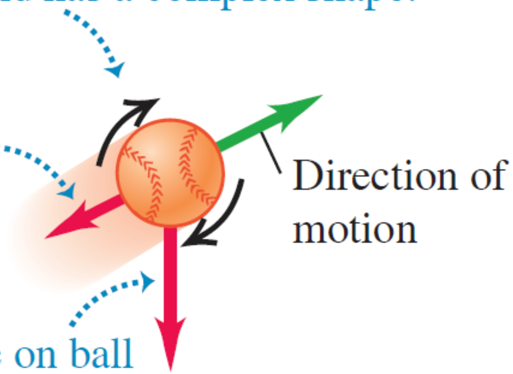
Note: physics is not simply a collection of facts and principles, it is also the **process** by which we arrive at general principles that describe how the physical universe behaves.

Idealized Models

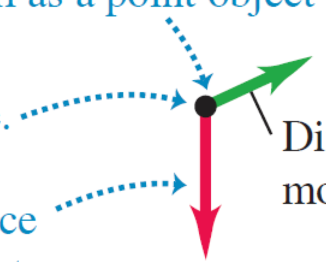
Meaning of a word
“**model**” in our daily life

Meaning of the word “**model**” in Physics

(a) A real baseball in flight



(b) An idealized model of the baseball



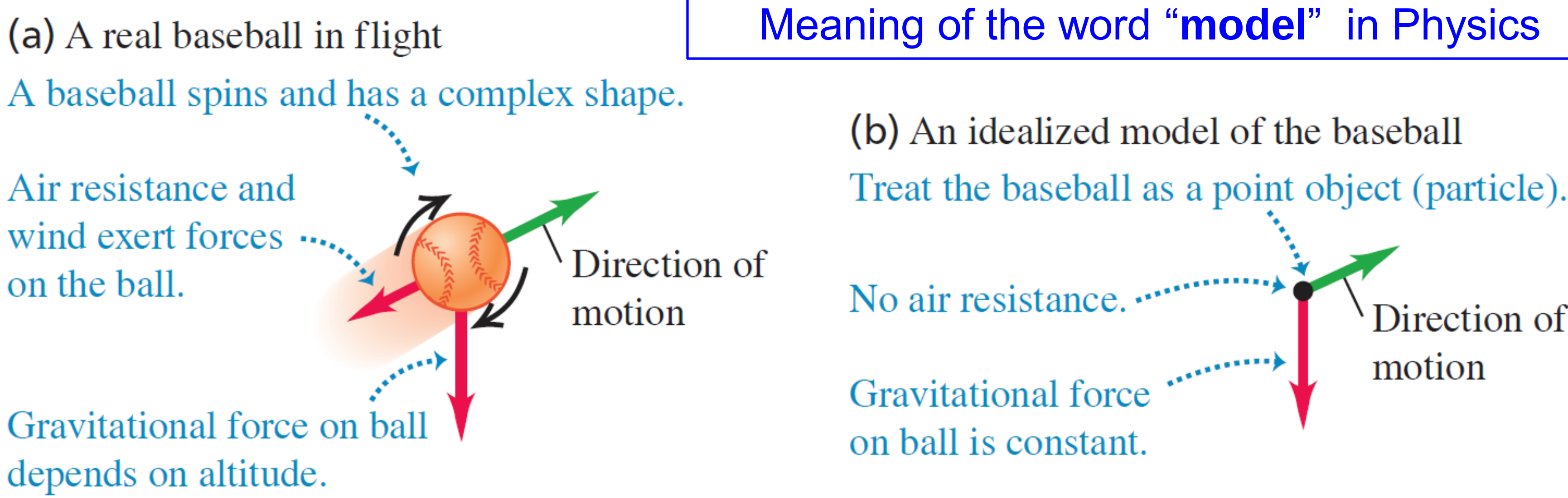
Idealized Models

In physics a model is a simplified version of a physical system that would be too complicated to analyze in full detail.

➡ a useful model simplifies a problem enough to make it manageable, yet keeps its essential features

❗ be careful not to neglect too much !

Meaning of the word "**model**" in Physics



Note: The validity of predictions we make using a model is limited by the validity of the model.

Fundamental Quantities

As it was mentioned above, physics is an experimental science. Experiments require measurements, and we generally use **numbers** to describe the results of measurements.

- any number that is used to describe a physical phenomenon quantitatively is called a **physical quantity**
- some physical quantities are so **fundamental** that we can define them only by describing how to measure them
- in other cases we define a physical quantity by describing how to **calculate** it from other quantities that we can measure

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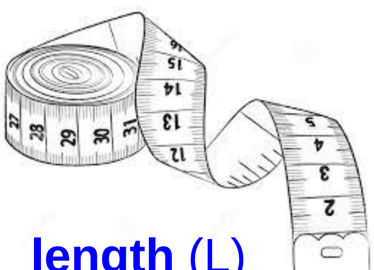
In **mechanics** the three most fundamental quantities are:



length (L)

mass (M)

time (T)

Standards of Length, Mass and Time

When we measure a quantity, we always compare it with some reference **standard**. Such a standard defines a **unit** of the quantity.

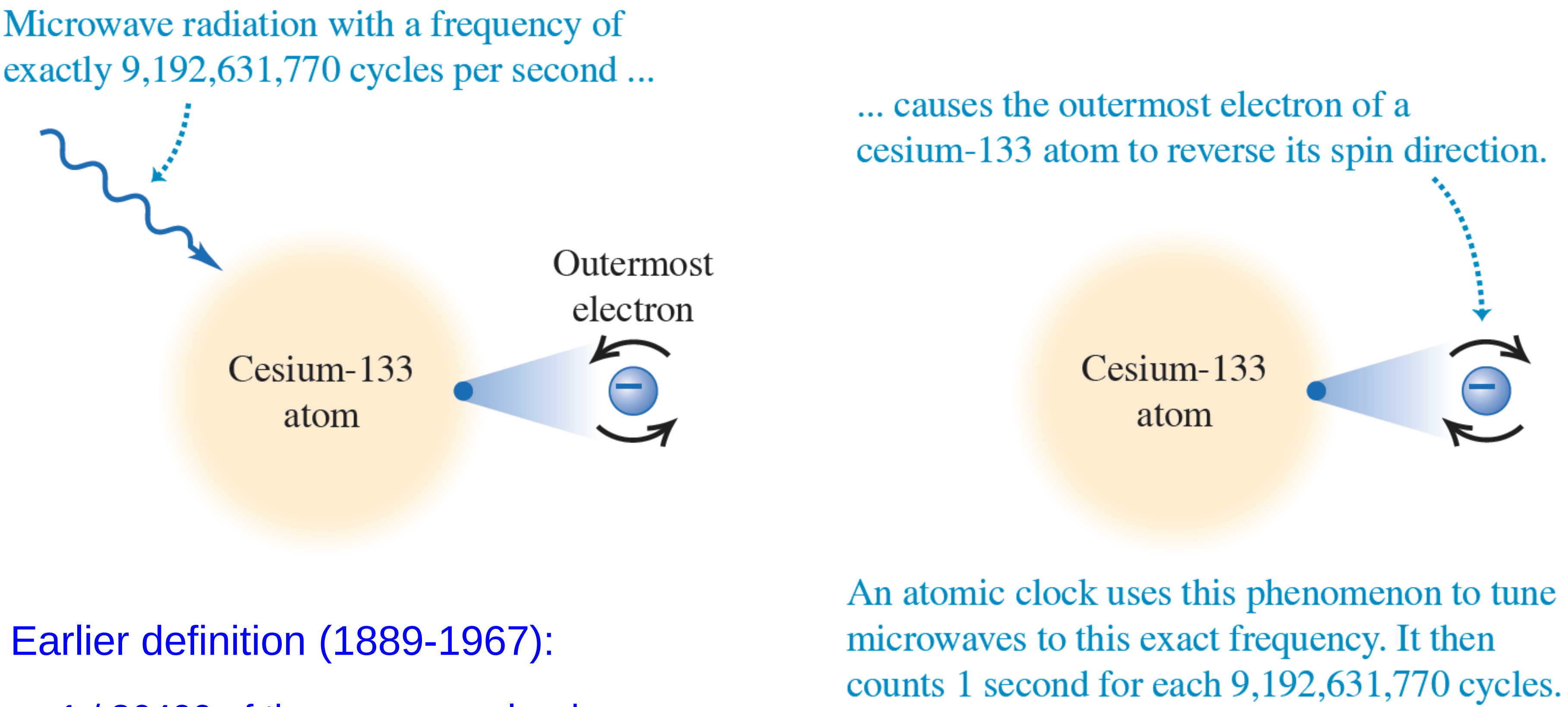
- defining units allows everyone to relate to the **same** fundamental amount
- to make accurate reliable measurements, we need units of measurement that do not change and can be duplicated by observers in various locations
- in 1960, an international committee agreed on a **standard** system of units for the fundamental quantities of science, called **SI** (Systéme International).

- **length** (L) → **meter** (m)
- **mass** (M) → **kilogram** (kg)
- **time** (T) → **second** (s)

Note: there are 4 more fundamental quantities (electric current, temperature, amount of substance and luminous intensity), which will be considered later in our course.

Time (s)

Definition since 1967: **1 second is 9,192,631,700 times the period of oscillation of radiation from the cesium atom.**

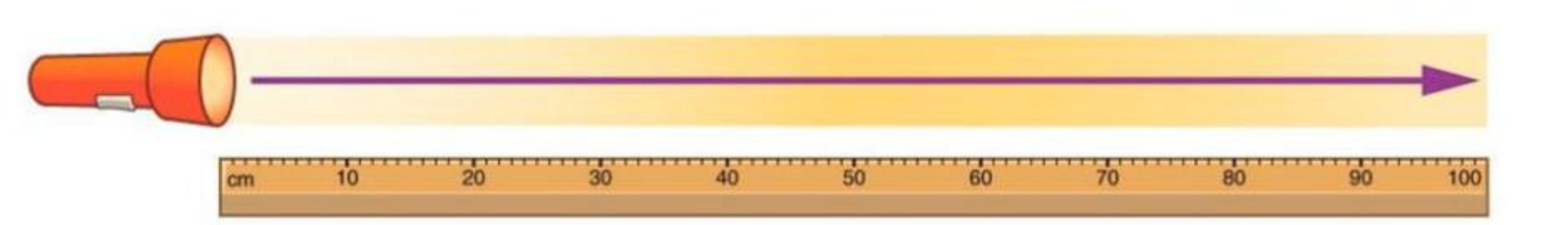


Earlier definition (1889-1967):

- 1 / 86400 of the average solar day.

Length (m)

Definition since October 1983: **1 meter is the distance travelled by light in vacuum during a time interval of 1 / 299,792,458 second.**



This definition is based on the **precise** value of *c*
299,792,458 m/s

Earlier definitions:

• 1793 – one ten-millionth of the distance from the equator to the North Pole;

• 1799-1960 – the distance between two lines on a specific bar stored under controlled conditions;

• 1960-1983 – 1 650 763.73 wavelengths of orange-red light emitted from a krypton-86 lamp

Mass (kg)

Definition since 2019 (!!!): **1 kilogram is defined by taking the fixed numerical value of the Planck constant *h* to be $6.62607015{\times}10^{-34}$ when expressed in the unit J·s, which is equal to $kg{\cdot}m^2{\cdot}s^{-1}$, where the meter and the second are defined in terms of *c* and $\Delta\nu_{Cs}$.**

In other words (earlier proposed definition):

The kilogram is the mass of a body at rest whose equivalent energy equals the energy of a photon whose frequency equals [$1.356392489652{\times}10^{50}$] hertz.

$$mc^2 = h\nu$$

Earlier definitions:

- the mass of a specific cylinder kept at the International Bureau of Weights and Measures in France

Approximate Values of Some Time Intervals

	time interval, *s*
Age of Universe	5×10^{17}
Age of Earth	1×10^{17}
Average age of college student	6×10^{8}
One year	3×10^{7}
One day	9×10^{4}
Time between normal heartbeats	8×10^{-1}
Period of audible sound waves	1×10^{-3}
Period of typical radio waves	1×10^{-6}
Period of vibration of atom in solid	1×10^{-13}
Period of visible light waves	2×10^{-15}
Duration of nuclear collision	1×10^{-22}
Time required for light to travel across a proton	3×10^{-24}

Approximate Values of Some Measured Lengths

	length, *m*
Distance from Earth to nearest star	4×10^{16}
Mean orbit radius of Earth about Sun	2×10^{11}
Mean distance from Earth to Moon	4×10^{8}
Mean radius of Earth	6×10^{6}
Typical altitude of satellite orbiting Earth	2×10^{5}
Length of football field	9×10^{1}
Length of housefly	5×10^{-3}
Size of smallest dust particles	1×10^{-4}
Size of cells in most living organisms	1×10^{-5}
Diameter of hydrogen atom	1×10^{-10}
Diameter of atomic nucleus	1×10^{-14}
Diameter of proton	1×10^{-15}

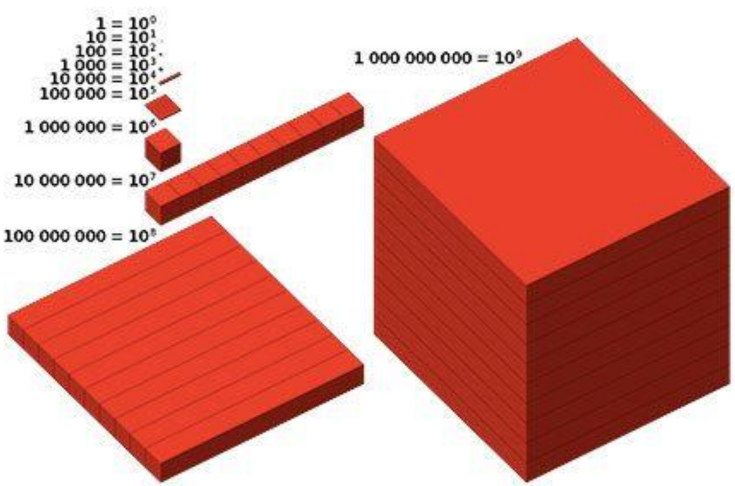
Approximate Values of Some Masses

	mass, *kg*
Observable Universe	1×10^{52}
Milky Way galaxy	7×10^{41}
Sun	2×10^{30}
Earth	6×10^{24}
Moon	7×10^{22}
Shark	1×10^{2}
Human	7×10^{1}
Frog	1×10^{-1}
Mosquito	1×10^{-5}
Bacterium	1×10^{-15}
Hydrogen atom	2×10^{-27}
Electron	9×10^{-31}

Prefixes for Powers of Ten

In order to express very large and very small quantities that we often encounter in physics, we use either **scientific notation** or the **prefixes**.

- prefixes correspond to powers of 10
- each prefix has a specific name
- each prefix has a specific abbreviation



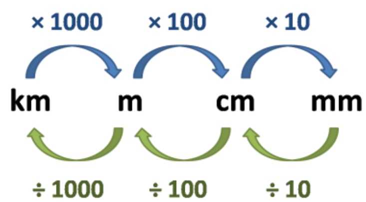
	Power	Prefix	Abbreviation
	10^{-18}	atto-	a
	10^{-15}	femto-	f
✓	10^{-12}	pico-	p
✓	10^{-9}	nano-	n
✓	10^{-6}	micro-	μ
✓	10^{-3}	milli-	m
✓	10^{-2}	centi-	c
	10^{-1}	deci-	d
	10^{1}	deka-	da
✓	10^{3}	kilo-	k
✓	10^{6}	mega-	M
✓	10^{9}	giga-	G
	10^{12}	tera-	T
	10^{15}	peta-	P
	10^{18}	exa-	E

✓ most frequently used in our course

Dimensional Analysis

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

Length →



In mechanics we use → **L M T** + [..]

$$[v] = \frac{L}{T} \qquad [A] = L^2$$

Dimensions and Some Units of Area, Volume, Velocity, and Acceleration

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

Dimensional analysis is a technique to check the correctness of an equation.

→ dimensions (as length, mass, time and their combinations) can be treated as algebraic quantities (we can *add* (!), *subtract* (!), multiply and divide them)

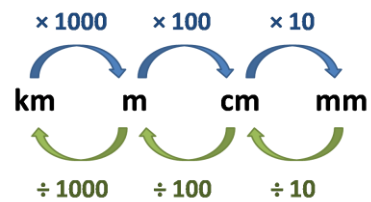
→ both sides of equation must have the same dimensions

Note: we can add or subtract quantities only with the same dimension!

Dimensional Analysis

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

Length →



In mechanics we use → **L M T** + [..]

$$[v] = \frac{L}{T} \qquad [A] = L^2$$

<u>Example</u>:

$$[a] = \frac{[v]}{[t]} = \frac{L/T}{T} = \frac{L}{T^2} = \frac{[x]}{[t]^2}$$

Note: the method cannot give numerical factors, this is its limitation

$$[x] = [a][t^2] \quad \Longleftrightarrow \quad x = \frac{at^2}{2}$$

It is a very good habit to use units in calculations, i.e. always write numbers with the correct units and carry the units through the calculation

if at some stage in a calculation you find that an equation or an expression has inconsistent units, you definitely know that there is an error

$$d = at = 4.0\,\frac{m}{s^{\cancel{2}}} \times 2{,}0\,\cancel{s} = 8{,}0\,\frac{m}{s} \neq m$$

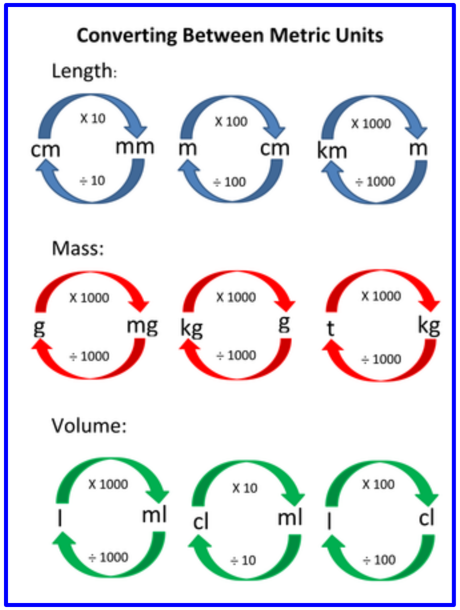
error!

Conversion of Units

Sometimes it is necessary **to convert** units from one system to another.

→ 1 km = 1000 m | 1 m = 100 cm | 1 cm = 10 mm | …

→ 1 h = 60 min | 1 min = 60 s | 1 h = 3600 s | …



Note: units can be treated as algebraic quantities that can "cancel" each other.

$$d = vt \quad \Rightarrow \quad 10\ \text{m} = \left(2\,\frac{\text{m}}{\cancel{\text{s}}}\right)(5\ \cancel{\text{s}})$$

Example #1: convert 15.0 inches to centimeters (taking that 1 in. = 2.54 cm)

$$15.0\ \text{in} = 15.0 \times (1\ \text{in}) = 15.0 \times (2.54\ \text{cm}) = 38.1\ \text{cm}$$

Example #2: convert 60 km/h to m/s.

$$60\ \frac{\text{km}}{\text{h}} = 60 \times \frac{1000\ \text{m}}{3600\ \text{s}} = \frac{60}{3.6}\ \frac{\text{m}}{\text{s}} \simeq 17\ \text{m/s}$$

Conversion factor

$$1.0\ \frac{m}{s} = 3.6\ \frac{km}{h}$$

Uncertainty in Measurements

Physics is a science, in which mathematical laws are tested **by experiment**. Hence, one has to deal with, which always have **uncertainties**.

- **no** physical quantity can be determined with complete accuracy because our **senses** are **limited** (even when extended with microscopes, cyclotrons, etc.)
- knowing the experimental uncertainties in any measurement is very important
- **accuracy** of the measurement depends on the sensitivity of the apparatus, the skill of the person carrying out the measurement, and the number of times the measurement is repeated
- in experimental work, determining how many numbers to retain requires the application of statistics and the mathematical propagation of uncertainties
- in our course it isn't practical to apply those sophisticated tools, but instead a simple method called **significant figures** will be used

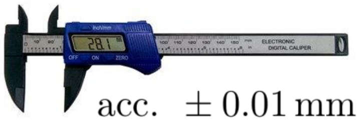
Uncertainty in Measurements

Example #1: Measuring the thickness of a metal plate with an ordinary ruler and a micrometer caliper

acc. $\pm 1\,\mathrm{mm}$

3.~~00~~ mm 2.8~~5~~ mm

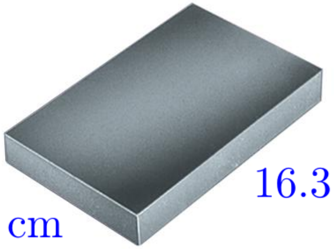
3 mm ✓



acc. $\pm 0.01\,\mathrm{mm}$

2.91 mm ✓

Example #2: Measuring the area of a metal plate with an ordinary ruler



acc. ± 0.1 cm

Length / width:

$$\boxed{\begin{array}{r} 16.3 \pm 0.1 \text{ cm} \\ \underline{4.5} \pm 0.1 \text{ cm} \end{array}}$$

Area:

$$\text{Min: } (16.3 - 0.1)(4.5 - 0.1) = 71.28 \text{ cm}^2 \qquad 71 < ??? < 75$$

$$\text{Max: } (16.3 + 0.1)(4.5 + 0.1) = 75.44 \text{ cm}^2$$

$$\text{Measured: } 16.3 \cdot 4.5 = 73.35 \text{ cm}^2 \approx \mathbf{\underline{73} \pm 2 \text{ cm}^2}$$

Significant Figures

Significant figure is a reliably known digit (other than a zero used to locate a decimal point).

➡ we will use significant figures to indicate the number of meaningful digits in the results of calculations

Rule #1. In **multiplying (dividing)** two or more quantities, the number of significant figures in the final product (quotient) is the same as the number of significant figures in the **least accurate** of the factors being combined, where the least accurate means **having the lowest number** of significant figures.

Result can have no more significant figures than the factor with the fewest significant figures:

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

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

+ rounding rule:

- if the last digit dropped is less than 5 – drop the digit
- if the last digit dropped is greater than or equal 5, raise the last retained digit by 1

$$25.3\underline{4} \approx 25.3 \qquad 16.7\underline{5} \approx 16.8$$

$$3.1\underline{7} \approx 3.2$$

Significant Figures

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Rule #2. When numbers are **added (subtracted)**, the number of decimal places in the result should be equal to the **smallest number** of decimal places of any term in the sum (difference).

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

$$27.153 + 138.2 - 11.74 = 153.6$$

• when working with very large or very small numbers, it is convenient to show significant figures by using the **scientific notation** (aka **powers-of-10 notation**)

$$384{,}000{,}000\ \mathrm{m} = 3.84 \times 10^8\ \mathrm{m}$$

Example: $123\,(0\ \text{dec.pl.}) + 5.35\,(2\ \text{dec.pl.}) = 128\,(0\ \text{dec.pl., not } 128.35\ !)$

$1.0001\,(4\ \text{dec.pl.}) + 0.0003\,(4\ \text{dec.pl.}) = 1.0004\,(4\ \text{dec.pl.})$

Significant Figures

Significant figure is a reliably known digit (other than a zero used to locate a decimal point).

➡ we will use significant figures to indicate the number of meaningful digits in the results of calculations

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What about zeros in digits? **Zeros are significant** when:

- between other non-zero digits
- after the decimal point and another significant figure
- can be clarified by using the **scientific** notations

$$1500 = 1.5 \times 10^3 \; (2 \text{ s.f.})$$

$$1500 = 1.50 \times 10^3 \; (3 \text{ s.f.})$$

$$1500 = 1.500 \times 10^3 \; (4 \text{ s.f.})$$

➡ two values with the **same** number of significant figures may have different uncertainties (compare 137 km vs. 0.25 km)

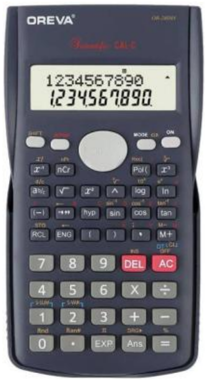
➡ when an integer or a fraction occurs in an algebraic equation, we treat that number as having no uncertainty at all (i.e., such a quantity possesses infinite number of significant figures)

$$v_x{}^2 = v_{0x}{}^2 + 2a_x(x - x_0) \Rightarrow 2 \text{ is } \textit{exactly } 2 \qquad (2.000000\ldots)$$

Significant Figures

Significant figure is a reliably known digit (other than a zero used to locate a decimal point).

we will use significant figures to indicate the number of meaningful digits in the results of calculations



Calculations involving **multiple steps**:

- keep extra significant figure(-s) in your **intermediate** calculations
- round the **final answer** to the correct number of the significant figures

$$\frac{2,5^2}{2} - \frac{1,4^2}{2}$$

$$2,5 \xrightarrow{1} \frac{(2,5)^2}{2} = 3,125$$

$$1,4 \xrightarrow{2} \frac{(1,4)^2}{2} = 0,98$$

$$„1\text{"} - „2\text{"} = 2,145 \approx 2,1$$

Significant Figures

EXERCISE

Task #1: A carpet is to be installed in a room of length 12.71 m and width 3.46 m. Find the area of the room, retaining the proper number of significant figures.

Solution:

Count significant figures:

$$\begin{array}{rclc} 12.71\ \mathrm{m} & \rightarrow & 4 & \text{significant figures} \\ 3.46\ \mathrm{m} & \rightarrow & 3 & \text{significant figures} \end{array}$$

Multiply the numbers, keeping only three digits:

$$12.71\,\mathrm{m} \times 3.46\,\mathrm{m} = 43.9766\,\mathrm{m}^2 \approx \mathbf{44.0\,m^2}$$

Significant Figures

EXERCISE

Task #2: Repeat the problem with task #1, but with a room measuring 9.72 m long by 5.3 m wide.

Solution:

Count significant figures:

$$\begin{aligned} 9.72\ \mathrm{m} \quad &\rightarrow \quad 3 \quad \text{significant figures} \\ 5.3\ \mathrm{m} \quad &\rightarrow \quad 2 \quad \text{significant figures} \end{aligned}$$

Multiply the numbers, keeping only three digits:

$$9.72\,\mathrm{m} \times 5.3\,\mathrm{m} = 51.516\,\mathrm{m}^2 \approx \mathbf{52\,m^2}$$

Estimates & Order-of-Magnitude Calculations

Getting an exact answer to a calculation may often be difficult or impossible, either for mathematical reason or due to limited information available. In these cases **estimates** can yield useful **approximate** answers that can determine whether a more precise calculation is necessary.

- estimates can serve as a **partial check** if the exact answer calculations are actually carried out

Order-of-magnitude estimation – approximate value within a factor of 10.

$$75 \sim 10^2 \qquad 1275 \sim 10^3 \qquad 8 \sim 10^1 = 10$$

- increasing a quantity by **three** orders of magnitude = increasing by a factor of 10^3 = **1000**

Other types (less crude):

$$\pi \sim 3 \qquad 27 \sim 30 \qquad 65 \sim 70$$

Estimates & Order-of-Magnitude Calculations

EXERCISE

Task #3: How many 100-RMB bills, stacked one on top of the other, would reach the Moon? The distance to the Moon is about 400 000 km.

Solution:

We estimate that 10 stacked bills form a layer of 1 mm. Convert mm to km:

$$\frac{10\,\text{bills}}{1\,mm}\left(\frac{10^3\,mm}{1\,m}\right)\left(\frac{10^3\,m}{1\,km}\right)=\frac{10^7\,\text{bills}}{1\,km}$$

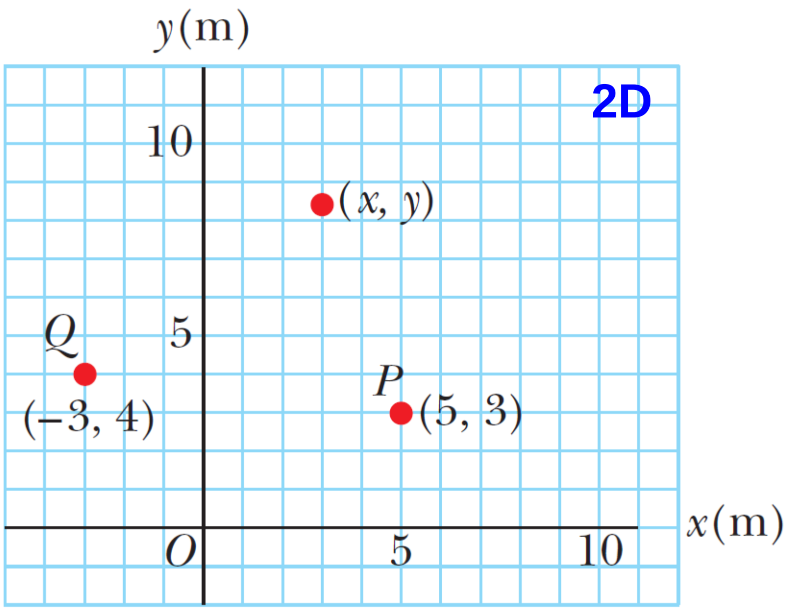
Multiply this value by the approximate lunar distance:

$$N\sim(4\times10^5\,km)\frac{10^7\,\text{bills}}{1\,km}=4\times10^{12}\,\text{bills}$$

Coordinate Systems

Many aspects of physics deal with locations in space. In order to specify a position of a point in space we need to introduce a **coordinate system**.

- point on a **line** – 1 coordinate
- point in a **plane** – 2 coordinates
- point in **space** – 3 coordinates



A **coordinate system** consists of

- a fixed reference point called the origin
- specific axes with scales and labels
- instructions on how to label a point relative to the origin and the axes

Cartesian coordinate system – is one of the simplest examples (aka **rectangular coordinate system**):

- x- and y- axes
- points are labeled as (x,y)

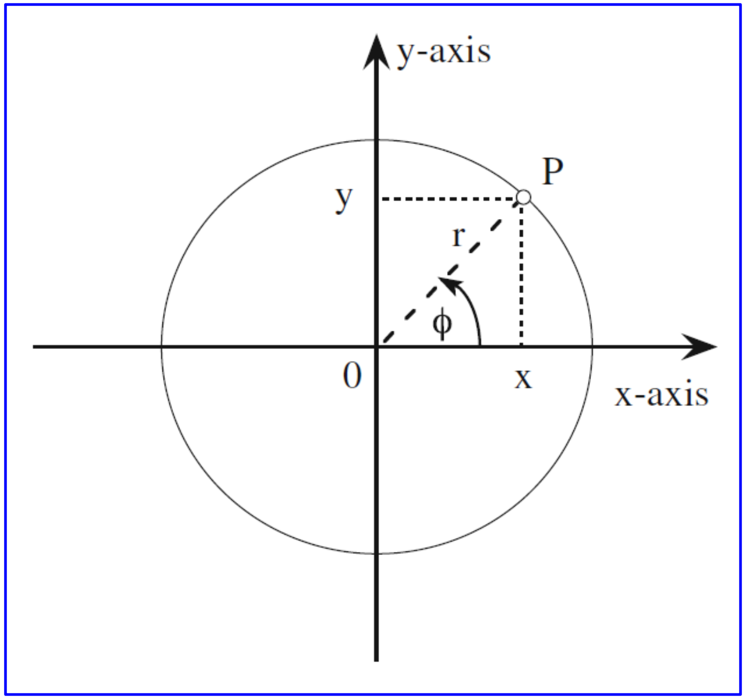
(3D) $\vec{r} = x\vec{i} + y\vec{j} + z\vec{k}$

Symmetry Adapted Coordinates

Sometimes it is convenient to take into account the symmetry of a physical system and replace Cartesian coordinates by **symmetry adapted coordinates**.

Important examples:

Plane polar coordinates (2D)



Coordinate notations: (r, ϕ)

Coordinate ranges: $r \geq 0, \quad 0 \leq \phi < 2\pi$

Transformation rules:

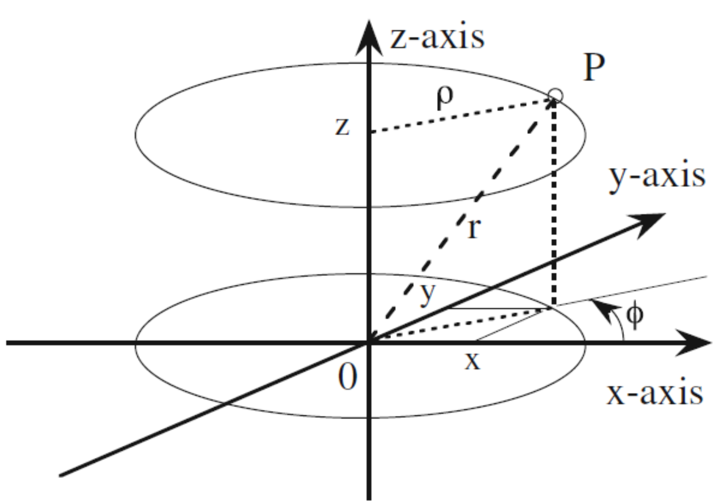
$$\begin{cases} x = r\cos\phi \\ y = r\sin\phi \end{cases} \qquad \begin{cases} r = \sqrt{x^2 + y^2} \\ \phi = \arctan\frac{y}{x} \end{cases}$$

Symmetry Adapted Coordinates

Sometimes it is convenient to take into account the symmetry of a physical system and replace Cartesian coordinates by **symmetry adapted coordinates**.

Important examples:

Cylindrical coordinates (3D)



Coordinate notations: (ρ, ϕ, z)

Coordinate ranges:
$$\rho \geq 0, \quad 0 \leq \phi < 2\pi, \quad -\infty \leq z \leq +\infty$$

Transformation rules:

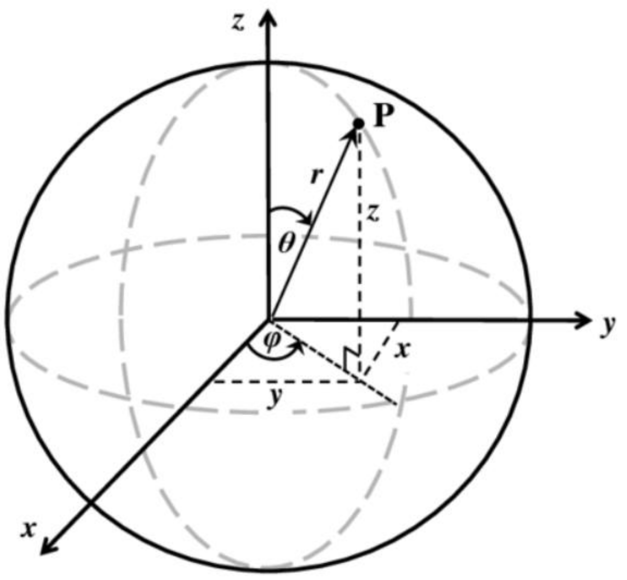
$$\begin{cases} x = \rho \cos\phi \\ y = \rho \sin\phi \\ z = z \end{cases} \qquad \begin{cases} \rho = \sqrt{x^2 + y^2} \\ \phi = \arctan \frac{y}{x} \\ z = z \end{cases}$$

Symmetry Adapted Coordinates

Sometimes it is convenient to take into account the symmetry of a physical system and replace Cartesian coordinates by **symmetry adapted coordinates**.

Important examples:

Spherical coordinates (3D)



Coordinate notations: (r, θ, ϕ)

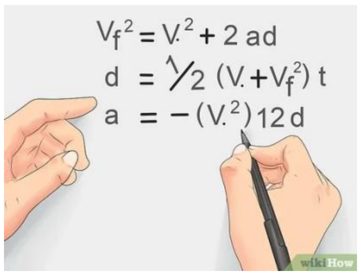
Coordinate ranges: $r \geq 0, \quad 0 \leq \theta \leq \pi, \quad 0 \leq \phi < 2\pi$

Transformation rules:

$$\begin{cases} x = r \sin\theta \cos\phi \\ y = r \sin\theta \sin\phi \\ z = r \cos\theta \end{cases} \qquad \begin{cases} r = \sqrt{x^2 + y^2 + z^2} \\ \theta = \arctan \frac{\sqrt{x^2+y^2}}{z} \\ \phi = \arctan \frac{y}{x} \end{cases}$$

Problem-Solving Strategy

Truly understanding a physical concept means that you are able to apply it to a variety of problems. Learning how to **solve problems** is absolutely essential. You don't know physics unless you can do physics.



- different techniques are useful for solving different kinds of physical problems
- however, there are certain key steps that you should follow, no matter what kind of problem you're dealing with

>> **I SEE** << STRATEGY

Identify

Set Up

Execute

Evaluate

✓ use the physical conditions stated in the problem to help you decide, which physical concepts are relevant

✓ identify the target variables

✓ identify the known quantities, as stated or implied in the problem

Problem-Solving Strategy

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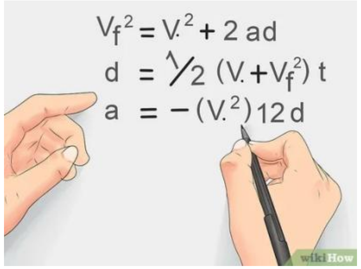

- different techniques are useful for solving different kinds of physical problems
- however, there are certain key steps that you'll always follow, no matter what kind of problem you're dealing with

>> I SEE << STRATEGY

Identify

Set Up

Execute

Evaluate

✓ given the concepts, known quantities, and target variables that you found in the IDENTIFY step, choose the equations that you'll use to solve the problem and decide how you'll use them

✓ make sure that the variables you have identified correlate exactly with those in the equations

✓ if appropriate, draw a sketch of the situation

Problem-Solving Strategy

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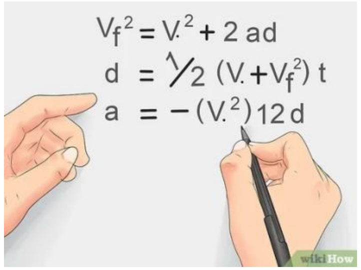

- different techniques are useful for solving different kinds of physical problems
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>> **I SEE** << STRATEGY

Identify

Set Up

Execute

Evaluate

✓ "do the math" with the equations that you selected in the SET UP step to solve for the target variables that you found in the IDENTIFY step

Problem-Solving Strategy

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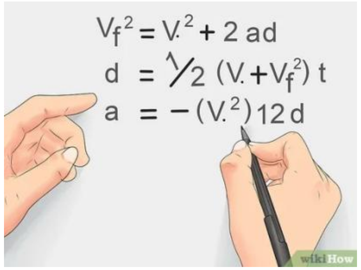


- different techniques are useful for solving different kinds of physical problems
- however, there are certain key steps that you'll always follow, no matter what kind of problem you're dealing with

>> **I SEE** << STRATEGY

- **Identify**
- **Set Up**
- **Execute**
- **Evaluate**

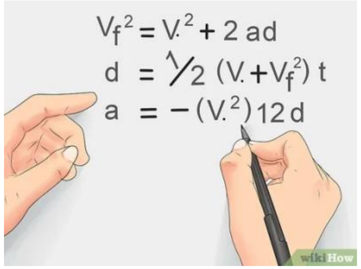
✓ check your answer from the EXECUTE step to see if it's reasonable

✓ if your answer includes an algebraic expression, confirm that it correctly represents what would happen if the variables in it had very large of very small values

✓ for future reference, make a note of any answer that represents a quantity of particular significance

Problem-Solving Strategy

Truly understanding a physical concept means that you are able to apply it to a variety of problems. Learning how to **solve problems** is absolutely essential. You don't know physics unless you can do physics.



- different techniques are useful for solving different kinds of physical problems
- however, there are certain key steps that you'll always follow, no matter what kind of problem you're dealing with

Some more comments:

- except for the few cases, try to make all mathematical rearrangements in letters avoiding substitution of numerical values until the final end; this may help you to avoid errors
- before writing any expressions or equations, try to imagine the whole picture and understand what is really taking place in the problem
- try to be attentive and concentrated because any error or typo in the beginning will nullify all your next efforts

Conclusions

- **physics** is both interesting and important science, which aims to provide our understanding of the physical world by developing theories based on experiments. For this purpose idealized **models**, which represent a simplified version of real systems are used

- **all** physical quantities can be expressed in terms of the **fundamental** quantities (in mechanics, we use **length** *in meters*, **mass** *in kilograms*, and **time** *in seconds*)

- **dimensional analysis** is a technique to check the correctness of the equation

- no physical quantity can be determined with complete accuracy. The concept of **significant figures** affords a basic method of handling these uncertainties

- **units** in physical equations must always be consistent. Use the table of conversion factors if needed

- making **estimates** is a useful technique in cases when getting an exact answer to a calculation is difficult or impossible, as well as in evaluating your answer for correctness

- **solving problems** is a crucial step in learning physics, do not neglect it

Homework

A list of **recommended** problems will be provided to you via a **separate PDF-file**.

Solving them is **NOT** obligatory !
(except for the cases of CHECKED homework problems, which will be announced explicitly in advance)

Nevertheless, I **strongly recommend** to do it in order to understand the topic better and gain new experience.
(the answers will also be provided)