K.Angoni, Physics Department, Vanier College

LECTURE 1

1. INTRODUCTION

- Physics is a science about the ***nature***; it deals with the *two* ***components of nature***: ***matter and fields***. The ***object*** of physics is the ***study of motion in nature.*** Physics builds ***"physical models"*** and make use of mathematics methods to describe or predict the ***MOTION (of objects with mass or the fields)"***.

-Mechanics has two main parts: *Kinematics and Dynamics.*
Kinematics describes the *motion of objects* without paying attention to the *reason why it happens*. It uses a set of parameters (***time***, ***position, displacement, velocity and acceleration***) to follow the evolution of the motion of an object in time.
Dynamics introduces ***forces*** and ***torques*** to *describe the actions* on an object and uses them to explain or predict the way an object moves. *Statics* uses "***forces and torques***" to explain ***<u>why</u>*** *the object of study is* ***at rest***. In general, *Statics* is included in the frame of *Dynamic*s. One uses two main object models in mechanic studies: " a *single material point* " or " *a set of multiple material points* " in motion.

- A kinematics' study starts by *defining the objective* (ex.- description *of a soccer ball motion)* and *the* ***reference frame*** where the motion is studied (ex.- *Ox, Oy along two sides of soccer field).* Then, one follows by *identifying the* ***necessary parameters*** for description of this motion (*time, position, velocity, acceleration*). Next, one records *a set of data* and *looks for* a possible *relationship pattern* between the measured data by using a graph. If a graphical pattern appears, one tries to get a mathematical function relating the parameters in graph by using a fitting line. Next, one ***builds a theoretical model*** to explain the observed graph and gets a *general mathematical relation* (or equation) that relates the parameters on the graph. After that, one ***uses the model and the relation to predict the numerical values of these parameters in any other similar situation.***

Example: ***<u>Object of study</u>***: *The* ***motion*** *of a glider on an air track (take Ox along track).*
<u>Parameters</u> ; *time, velocity, acceleration*.

Looking for a pattern by using a graph:

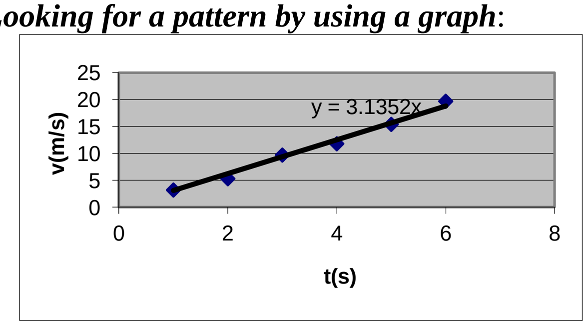


Figure 1

<u>Measured data</u>:

t(sec)	1	2	3	4	5	6
υ(m/sec)	3.2	5.3	9.7	11.8	15.4	19.7

<u>Getting a mathematical relation from the graph</u>.
One builds a graph with recorded data, uses a linear fit and find out a the relationship **υ**(*m/sec*) = 3.135***t**(*sec*)

<u>Building a model</u>: One *models the glider as* a ***<u>material point</u>*** (with mass = $\mathbf{m_{gl}}$) and considers the motion of this point at *constant* ***acceleration*** ***a = υ / t***. From this model and the graph it comes out that the glider moves as a *material point* at acceleration a = 3.135m/s^2.

2. UNITS

- A *physical parameter* has *a numerical value and a unit of measuremen*t (<u>don't forget units</u>)!
The numerical value shows how many units are contained inside the measured parameter.
In physics, one discerns between the ***basic units*** and the ***derived units***.

a] A ***basic unit*** is a unit used during a ***direct comparison***. In this case the numerical value of the physical parameter is equal to the number of times the basic units enters into the parameter in consideration. (Example; When measuring the parameter "length" of a desk, one has to define first

what unit will use - *say meter*. Then one measures how many times the *meter unit* enters into the length of the desk - say 2.5 times. So, one gets that the desk length is *2.5 meters*.)
The *basic units* are selected by referring to the human experience for most common measurements.
The ***basic unit*** for the ***physical parameter "length"*** is the ***meter (m)***. The **standard** for the length ***one meter*** (kept in Sevres, France), is defined as the distance between two fine scratches on a special material bar. *All meter units used over the world must have a length equal to this standard.*
The ***basic unit*** of ***the physical parameter "time"*** is the ***second (s).*** The **standard** ***of one second is the time light takes to travel over a distance 299 792 458 m (~3*10⁸m) in vacuum.***
All second units used over the world are equal to this standard.
The ***basic unit*** for ***"mass"*** is the ***kilogram (kg)*** and it is defined as the ***mass*** of a ***particular metal cylinder*** kept in Sevres. *All kilogram units used over the world must be equal to this standard.*
The ***meter, sec, kg*** *are* **the three basic units** *in* ***SI system***[1] *of units (System International).*

- Even though the SI unit standards were selected to produce reasonable numerical values[2] for common measurements, the continuous increase of human activity requires dealing with numerical values which are very big or very small if referred to the SI units. To avoid the use of very big or very small numerical values, one has introduced the " *sub* and *over* " units:

SUB-UNITS	**length**	**time**	**mass**
x10^{-2} «centi»	10^{-2}*m* = ***centi****metre(cm)*	- *no use*	- *no use*
x10^{-3} «milli»	10^{-3}m = ***milli****metre(mm)*	10^{-3} *s* = *millisecond(ms)*	10^{-3}*g* = *milligram(mg)*
x10^{-6} «micro»	10^{-6}m = ***micro****meter(μm)*	10^{-6} *s* = *microsecond(μs)*	10^{-6}*g* = *microgram(μg)*
x10^{-9} «nano»	10^{-9}m = ***nano****metre(nm)*	10^{-9} *s* = *nanosecond(ns)*	10^{-9}*g* = *nanogram (ng)*
x10^{-12} « pico »	10^{-12}m = ***pico****metre(pm)*	10^{-12}*s* = *picosecond(ps)*	10^{-12}*g* = *picogram (pg)*
x10^{-15} « femto»	10^{-15}*m* = *femtometre(fm)*	10^{-15} *s* = *femtosecond(fs)*	10^{-15}*g* = *femtogram (fg)*

OVER – UNIT x$\mathbf{10^3}$ " ***kilo*** " (ex.-10^3m = kilo*metre);*
x$\mathbf{10^6}$ *"Mega"* x$\mathbf{10^9}$ *"Giga"* x$\mathbf{10^{12}}$ *"Tera"*

Also, in everyday practice, one uses other *particular units* like:
1ton (= 10^3kg), 1min(=60s), 1hour (= 60 min), 1day (=24 hours) and 1year (=365.25 days).

- Some countries, for historical reasons, use several *different units*. For example, in United Kingdom, one expresses the length in miles (***mi***) or inches (***in***). (One may see the speed given in ***Km / hr*** and ***miles/hr*** in some cars). *How to find the value of a physical parameter in a given unit when we know its value in another unit? This question is answered by* the ***procedure of unit conversions*** (see section 4).

b] A ***derived unit*** is a unit that is expressed "as a math expression" of the ***basic units***.
Examples: the volume is expressed in m^3; the density of a liquid is expressed in kg/m^3.. **There are three basic units (***in SI system*** m, sec, kg) and many derived units (m^2, m^3, N, m/s, m/s^2…)**

3. DIMENSIONAL ANALYSIS

- In physics, one uses often expressions of type " *this parameter has length* ***dimensions*** ". So, without being interested on a precise unit (like ***meter, mile, cm*** ..) one confirms that the parameter is expressed in ***length units***. One uses the letters "***L*** for length", " ***T*** for time " and "***M*** for mass" to show the three ***types***

[1] We will use mainly SI units in our course.
[2] Nor to big neither to small

of ***basic dimensions.*** When referring to the ***dimension*** of a given physical quantity one uses the square brackets. ***Ex***.[a] = LT^{-2} for the ***dimension of acceleration*** or [μ] = M/L for the dimension of linear mass density. Suppose that theoretical calculations produce *an algebraic expression for a parameter*. Often, one uses the dimensional analysis as a *first step verification*. (Ex.; if one gets the expression Z = X + A for Z , at first, one has *to make sure* that dimensions [X] and [A] are equal because one cannot add up different physical quantities; say, *position + acceleration*!!). So, before proceeding to numerical calculations, one must *verify the* ***dimensional consistency*** of the found expression.
Ex.: If a calculation gives for *acceleration* the expression $a = m*t^2/v$, by verifying the dimensions;

$[a]=\frac{[m]*[t^2]}{[\upsilon]}=\frac{M*T^2}{L/T}=M*T^3*L^{-1}$ one finds out that it is a wrong expression because [a] = LT^{-2}.

4. CONVERSION OF UNITS

Often, one needs to convert the numerical value of a parameter from a given unit to another unit.
"***How to convert the value of a physical parameter from a given unit to another unit"?***
One can do this by the following *steps*:
- Start by writing the ***conversion factors***; Ex: 1 h = 60 min; 1 h = 3600 s; 1mi = 1.609 km
- Write their ratios as equal to 1; (1h/60min) =1 or (60min/ 1h) =1; (1h/3600s) = 1; (1mi/1.609km) =1.
- Then, as the ***multiplication by 1 does not change a calculation result,*** *you may multiply by ratios*;

Ex_1: The *distance* between two cities is 425km and we wants to find it in miles. From the manual *1 mi =1.609Km*. So, $\frac{1mi}{1.609km}=1\_and\_425km=425km*1=425km*\frac{1mi}{1.609km}=264.4mi$

Ex_2: Convert the *speed* 60*km/h* to *m/s*. As *1km = 1000m*, ***1000m /1km =1; also 1h/3600s =1.***

So, $60km/h=60\frac{km}{h}*1*1=60\frac{km}{h}*\frac{1000m}{1km}*\frac{1h}{3600\sec}=16.67m/s$

Ex_3: The *area* of a paper sheet is 6580cm^2. Convert it in m^2. Knowing that ***1 m = 100cm*** and

$$6580cm^2=6580cm*cm=6580(cm*\frac{1m}{100cm})*(cm*\frac{1m}{100cm})=6580(1m/100)(1m/100)=0.658m^2$$

Ex_4 $1in^2=1[in*1]^2=1[in*2.54cm/in]^2=[2.54cm*1]^2=[2.54cm*1m/100cm]^2=[2.54*10^{-2}m]^2=6.4516*10^{-4}m^2$;

Ex_5 *1 liter(l)* $=10cm*10cm*10cm=10^3\ cm^3=10^3\ [cm*(1m/100cm)]^3=10^3[10^{-2}m]^3=10^3*10^{-6}m^3=10^{-3}m^3$

5. SCIENTIFIC NOTATION

- Often, one has to deal with ***very big*** or ***very small*** numerical ***values*** of a physical parameter. The s***cientific notation*** helps to *simplify* the calculations in these cases. When written in scientific notation, a numerical value is presented as a number with ***one digit before the decimal point*** *multiplied by a power factor of 10*. (Ex. $\mathbf{1.253x10^{+8}}$ ***;*** $\mathbf{-8.253x10^{-38}}$ ***;*** $\mathbf{0.253x10^{-3}}$ ***or*** $\mathbf{2.53\ x10^{-4}}$).
The *scientific notation* of a number is known also as its ***exponential presentation with base 10.***
- To present a number in scientific notation, one shifts the decimal point to the right or the left until one get ***only one digit*** *(in general non-zero)* ***before the decimal point***. To *keep the same value* of number, for each **left shift of decimal point one multiplies by 10** and for each **right shift one divides by 10**.
(**Ex:** $125.4 = 125.4 *10^0 = 12.54 *10^1 = 1.254 *10^2$;
$0.001254 = 0.001254 *10^0 = 0.01254 *10^{-1} = 0.1254 *10^{-2}= 1.254 *10^{-3}$

- Basic operations with scientific numbers. Given two numbers: $x_0 = a_0 10^{b_0}$ _ $x_1 = a_1 10^{b_1}$

$x_0 * x_1 = (a_0 a_1) * 10^{b_0 + b_1}$ and $x_0 / x_1 = (a_0 / a_1) * 10^{b_0 - b_1}$

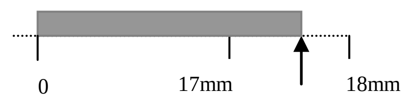
Ex: $(5.67*10^{-5})*(2.34*10^{2}) = 13.2678*10^{-3} = 1.32678*10^{-2}$; $(5.67*10^{-5})/(2.34*10^{2}) = 2.423*10^{-7}$

Before performing *addition* or *subtraction,* the numbers ***must be presented by the same exponent. Usually, the smaller number is transformed before performing the addition or subtraction.***

Ex: $3.17*10^{-5} + 1.34*10^{-4} = 0.317*10^{-4} + 1.34*10^{-4} = 1.657*10^{-4} \cong 1.66*10^{-4}$ (sig.fig.rule)
$2.13*10^{6} - 5.34*10^{2} = 2.13*10^{6} - 0.000534*10^{6} = 2.130534*10^{6} \cong 2.13*10^{6}$(sig.fig.rule)

6. SIGNIFICANT FIGURES AND ROUNDING OFF

- Often, one refers to the "*half of used unit*" to define the ***absolute uncertainty of a measurement***. Assume that one uses a ruler with **minimum unit 1mm**, when measuring the length of an object and reports the result of measurement as L = 17.5mm. This means that ***its length is estimated*** with ***three significant figures where the last digit*** "5" ***is meaningful but not certain.***
In this example, the ***best estimation*** is 17.5mm, the ***absolute uncertainty*** is 0.5*mm and* ***the true length*** value *is inside* ***the uncertainty interval*** *(*17.5 ± 0.5) mm.



Note: *If the mass of an object is reported 15.5g, this implies that the* ***uncertainty*** *is 0.5g but if reported 15.55g, this implies it 0.05g.*
The **concept of significant figure** ***(****reliable or meaningful digit****)*** is related to ***measurable*** **parameters.** If the length is reported as *12.345m* , this is a number with *5* significant figures "***SF***" where l**ast *figure*** *"5"* is *reliable but* ***not certain.*** This implies that **the minimum unit used** in that measurement **is 0.01m** (=**1cm)** and the **observer is able to distinguish without being sure** a length of **0.005m = 0.5cm = 5mm.**

- Considering a data treatment calculation, one has to keep in mind that:
  a) a ***calculated*** **parameter cannot be more *precise* than the parameters included in calculations.**
  b) the ***number of decimal digits at absolute uncertainty*** *and* ***best estimation*** *value* ***must be equal*.**

Example. Assume that one uses a meter stick with 1 cm unit (so, **Δ = 0.5cm**) to measure the length of a *set of 6 wood sticks* and gets values 16.5,19.5,17.5, 18.5, 18.5, 19.0cm.
Calculation: Then, one calculates the *best estimation* (i.e. *average*) length of the set as L_{Av}=18.25 cm and the absolute *uncertainty* (i.e. mean deviation) as ΔL = 0.83333cm.
Sig.figure : As each measurements cannot be more precise than ±0.5cm(**first decimal is uncertain**), there is **no sense to keep more than one digit after decimal point at the results**. The other decimals **have *no reliability***; one should *round off* to one decimal digit (18.2 ±0.8)**cm.**
The absolute uncertainty (±0.8) is a measure of data spread and its decimal (.8) has uncertain value.

- How to define the significant figures? ⇨ ***Several rules in finding the significant figures***
1) All **nonzero digits** are significant: 1.324 g has **4 sign. fig.**; 1.5 g has **2 sign. fig.**
2) **Zeroes between nonzero digits** are significant: 3002 kg has **4 sign. fig.** 1.02 L has **3 sign. fig.**
3) **Leading zeros** to the left of the first nonzero digits are not significant; 0.001g has **1 sign. fig.**
Such zeroes merely indicate *place holders* and they *do not contain* any *information* about the *uncertainty of estimated parameter*. Often one *uses the* **scientific notation to get rid of place holder zeroes**. 0.012 g has **2 sign.fig.** ***Ex***: $0.0001035 = 1.035*10^{-4}$ (**4 sign.fig**)
4) **Trailing zeroes (**to the *right end) are significant* ***only if there is a dec. point.***
0.0230m (**3 sign.fig.)**; 0.20g (**2 sign.figs**.); 100 =$1*10^{2}$ (**1 sig.fig.**); 100.0 =$1.000*10^{2}$ (**4 sign.fig.)**

5) In **scientific notation** the significant figures are count at the coefficient. ***Ex.*** The ***length*** 5.5mm has **2 sig. fig.** Even if converted in meters, i.e. 0.0055m, it can be written $5.5*10^{-3}$ m(2 ***sig. fig.***). 2.02×10^4 kg has **3 sign. fig.;** 2.020×10^4 *ft* has **4 sign.fig.** but 2.0200×10^4 *N* has **5 sign. fig.**

6) In ***addition and subtraction***, the result is rounded off to the *smallest number of **decimal place**s* occurring in all components. 200.(**no decimals**) + 25.643 (**5 sign. figures**) = 225.643 which should be rounded off to 226. (**no decimals**).

This dot means that 0 is the last significant (but uncertain) digit and not a place holder.

In ***multiplication and division***, the result should be rounded off so that it has the same number of significant figures as in the **component with the *smallest number of significant figures***.

- 4.0 (**2 sign. figures**) × 13.60 (**4 sign. figures**) = 54.400
  which should be **rounded off** to 54**.** (**2 sign. figures**, "4" is significant but uncertain).
- 12.589(**5 sign. figures**) x 2.0312(**5 sign. figures**) / 4.0 (**2 sign. figures**) = 6.3926942
  which should be rounded off to 6.4 (**2 sign. figures**, "4" is significant but uncertain).

7) Rounding off rule: *When rounding off, consider **only** the first number to the right of the assumed uncertain digit and disregard the following digits.*

Ex: For **two significant figures;** 18.61 is rounded to 19**.** ; 18.47 to 18**.** and 5.249 to 5.2

Note: I***f the digit to be dropped is 5 followed by a 0 digit leave the uncertain digit as it is, otherwise increase it by 1.*** Ex: For **two significant figures;** 18.50 is rounded to 18 but 18.51 is rounded to 19**.**

Basic principle in numerical calculations: **The result of calculations cannot be more *precise* than parameters included in calculations**. Step-by-step procedure:

1- Identify the *sig.fig*. and the *number of decimals* for each participating number before calculations.
2- Identify the **smallest sig.fig** for multipl./div. and **smallest number of decimals** for subtr./add..
3- a. After each mathematical calculations identify the corresponding sig.fig. or number of decimals.
   b. At the end, round off the numerical result by referring to smallest **sig.fig**. of input numbers.

Ex: 124.4 + 2.345 –11.005 = 115.74 and by rounding of **(to 1 digit after dec. point)** we get 115.7
(5.345 +12.3005) / 2.2 = 8.02068 and by rounding off **(to smallest sig.fig. 2 sig.fig)** we get 8.0
$(2.365*10^{-15} * 0.0287) / 1.23*10^{-12} = (2.365*10^{-15} * 2.87*10^{-2}) / 1.23*10^{-12} = 5.518333*10^{-5}$
and by rounding of **(to smallest sig.fig. 3 sig.fig)** we get $5.52*10^{-5}$

*Note: The **EXACT** numbers like 4(cars) or 10(students) have "**no uncertain digits**"; or one has to add an infinite number of zeroes after last given digit to "**approach to the uncertain digit**". Exact numbers have **INFINITE SIG. FIGURE and INFINITE number of DIGITS after decimal point**.*

Ex: 4.795 / 145 = 0.033068966 must to be rounded to 0.03307 because $Sig.Fig_{min} = 4$ (at 4.795)
but if "145 ≡ 145." it is *not an exact number* and the result is 0.0331 because $Sig.Fig_{min} = 3$ (at 145.)
156.3 - 11 = 145.3 *if "**11**" stands for an exact number* because of infinite zeros after dec. point while it has to be rounded off to 145. for "***11***." which *is not an exact number* (it has **zero decimals).**

Convert: a) 524cm in km b) 58.5 liters in m^3 (1liter = $1dm^3$ and 1m=10dm) c) 100km/h in m/s
Convert & calculate in Scientific Notation: a) 0.0000025 b) 125368 c) 0.2003 d) 123.005 e) 0.125*123.5 f) $(5.12*10^4*0.001)/230$
Find the significant figures: a) 0.025 b) 0.0205 c) 0.02050 d) 12.35 e) $5.05*10^6$ f) $2.10025*10^{-4}$
Round off the result by using the sig. figures: a) 5.1 + 0.25 b) 0.01-12 c) 0.01-12. d) $2.14*10^5/0.2$ e) (3.14-0.02)/2

PRACTICAL RULE; **If you are using a formula to calculate a parameter but the values for parameters in expression are given without decimal point, keep just 1 or 2 digits after the decimal point at the result.**

-As mentioned in introduction, one may record a set of data to check if there is a relation between two parameters " ***x*** " and " ***y*** ". After including their values in a table, one can draw a graph and verify if the *experimental points*[3] *are distributed around a line*. If this is the case, one can *affirm the existence of a* ***relationship*** between the two considered physical quantities. Otherwise, one says that there is no observable relation between them. In case of visible relation, one might try to fit the data by a function; in general, one uses a ***linear or power fitting*** *function*.

a] LINEAR RELATIONSHIP

-If the experimental points are distributed around a **straight line**, one says that the *quantity* " ***y*** " varies ***linearly*** with *quantity* " ***x*** ". In the *particular case* when the *straight line passes through the origin* one says that the quantity " ***y*** " is ***proportional*** to quantity " ***x*** " . In proportional relations, the ratio " ***y*** / ***x*** " is a constant and is called ***proportionality constant*** (4 in the case of figure). In case of proportional relationships, if one of quantities is multiplied by a factor the other one is multiplied by the same factor, too (Ex. if ***x*** is increases 3 times, ***y*** increases 3 times, too, because their ratio must remain unchanged, 4). This is *not true for linear relationships* (*verify for the linear relation in figure y = 2x + 1.5*).

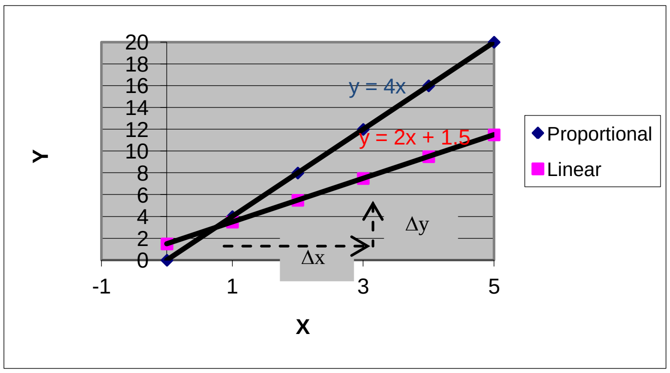


Figure 2

- The general ***mathematical expression*** for ***linear relations*** has the form Y = ***a****X + ***b***
Note that "***a"*** coefficient is equal to the *slope of straight line* and "***b"*** coefficient is equal to the y value at the point where the straight line touches Y-axis. The slope of a linear relation may be positive ("+2", "+ 4" in fig.2) or negative ("–3" in fig.3).

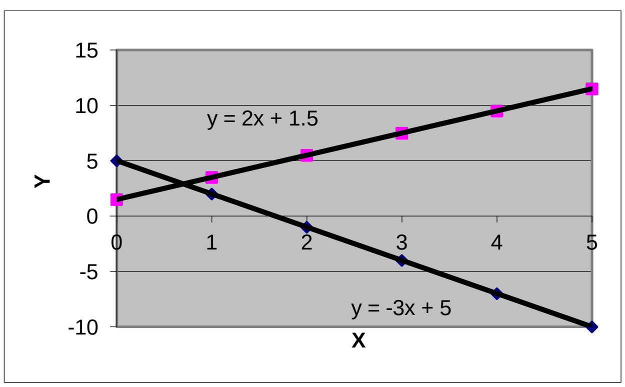


Figure 3

In physics, there are many ***linear*** and ***proportional*** relationships. Here are some of them:

<u>Proportional</u>:

Force to *acceleration*	F = m*a
Elastic force to *extension*	$F_{el} = - k*\Delta x$
Electric *tension* to *current*	U = R*I

<u>Linear</u> :

Velocity to *time*	$\upsilon = a*t + \upsilon_0$
Length of a metal bar vs. *temperature*	$\boldsymbol{l} = c*T + \boldsymbol{l_0}$

b] POWER RELATIONSHIP

-If the experimental points are distributed around a line which ***slope changes***, one says that the relationship between quantities X and Y is described by a ***curve***. In general, a *curve can be fitted by power expressions*. The following simpler forms are met often in physics.

[3] Each point on the graph corresponds to a given experimental data couple (x, y)

- ***Parabolic relationship $Y = a * X^2$*** is centered to origin and the constant ***a*** takes different values.
Example: You know (form high school) that free fall acceleration close to earth surface is g[4] $= 9.8m/s^2$ and if an object is left to *fall* from *rest* at a given point O, the distance from O will increase in time as $y = g\,t^2/2$ which is a parabola centered at origin. If the experiment gives a set of y_i, t_i values, then

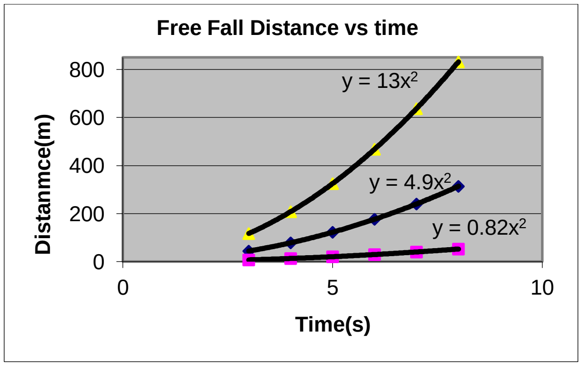


Figure 4

the ratios (y_i/t_i^2) will have "*the same value*" $(y/t^2) = g/2 \sim 4.9$ (= 9.8/2) for any moment t.
If one would repeat this experiment on Moon surface, one would get $(y/t^2) = a/2 \sim 0.82$. On Jupiter surface one would get $(y/t^2) = a/2 \sim 13$. So, one *may assert the following general physics' law*: **During the free fall, the distance of object from starting location increases in parabolic way with time.**
*Note that the **a**- value depends on the planet.*

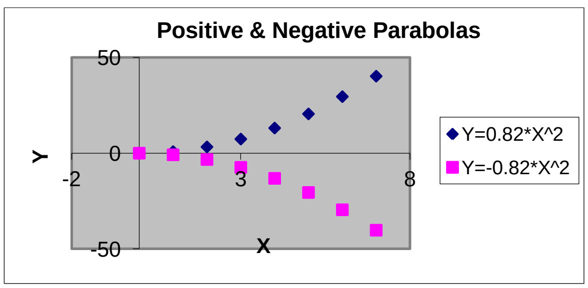


Figure 5

- Depending of the "***a***" sign , one can discern a **positive** from a **negative parabola**.
The graphs in figure 5 show two examples.
Note: The general mathematical expression for a parabola is $y = a*x^2 + b$. If $b \neq 0$ the parabola top is not located at the origin of coordinative system.

- ***Inverse relationship $Y = const/X$***. This type of relationship must be considered when **one** of the measured quantities **decreases** while the **other one increases**. Verifying whether *the product Y*X is almost constant for all measured data constitutes the first step trial*. If this is **true** one can confirm that the ***Y and X are related by an inverse relationship***. (Ex. *When compressing a gas in a container its pressure **P** increases while its volume **V** decreases but the product **PV** remains constant.*)

- ***Inverse square relationship $Y = const / X^2$.*** This is the mathematical form of *gravitational forces* exerted between two objects at ***distance R***$(F = const / R^2)$. As shown in figure 6, the real difference between ***Inverse*** and ***Inverse Square*** relationships appears clearly only for small values of argument X.

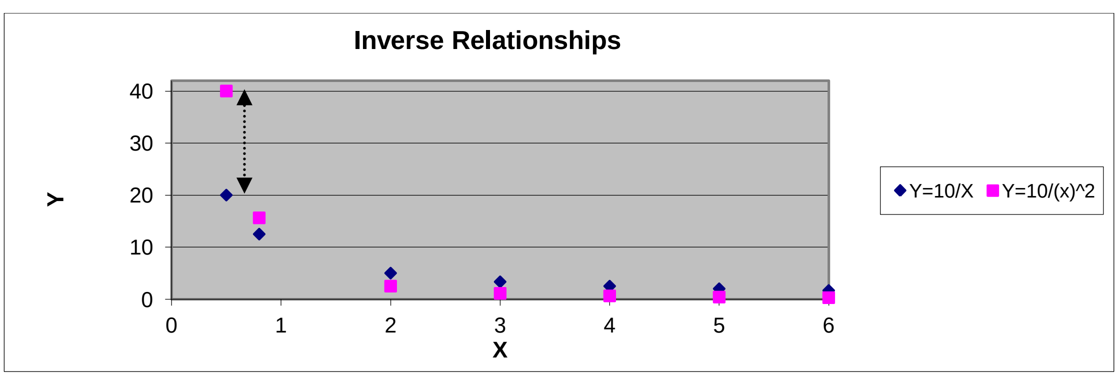


Figure 6

[4] Gravitational acceleration on earth surface

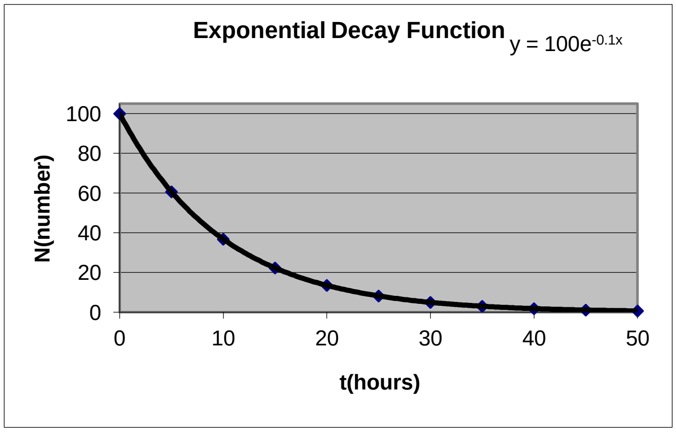


Figure 7

- ***Exponential relationship*** ***Y = a*Exp[b*(X- c)^d]***. It is very common in physics. Its' graph takes different forms in dependence on the values of parameters ***a, b, c, d***. One well known example is that of radioactive nuclei which number decreases in time following the exponential expression $N = N_0 Exp(-\lambda * t)$. One can get this expression from the general one if ***a*** = N_0, ***b = -λ***, ***X= t***, ***c = 0*** and ***d =1***. The figure 7 presents the graph of function

$$Y = 100 * Exp[-0.1 * t]$$

8. FINDING THE ORDER OF MAGNITUDE OF THE CALCULATION RESULT

This is an "estimation" of the size of the result of an expression *within an* **order** *of "**10**"*. One makes *approximations* to get *estimations as orders of magnitude. It is very useful in answering questions like "estimate the daily consumption of fruits in a city with 3 millions of habitants"*. One may start by assuming a consumption *" say " ~0.5kg fruits/day/person* and follows $3*10^6*0.5 = 1.5*10^6$ i.e. essentially (***as an order of magnitude***) 10^6kg.
The basic technique in those estimations consists to substitution of *each input number by the* ***closest number*** *presented as " **10** ^{x}"*. Next, one performs the calculations.

Example: $$2.135 + \frac{898.475*10.812}{7.891} \approx 10^0 + \frac{10^3*10^1}{10^1} \approx 10^0 + 10^3 \approx 10^3 = 1000$$

The precise answer is 1233.19 and it has the same ***order of magnitude*** (one thousand) as 1000. Estimating first the order of magnitude helps to get an idea when there is no precise information about relevant parameters and also helps to prevent arithmetical mistakes. Say, if the normal step-by-step calculations give 12331.9 , one sees quickly the existence of a mistake.

SUMMARY

- The Universe is constituted by Matter (*objects with mass*) and Fields (*objects without mass*). Physics studies the motion in Matter and Fields. ***Physics is essentially an experimental science; even if a study may start theoretically, it cannot be* officially accepted *without experimental proof***.
 Mechanics is a part of physics that deals with motion of objects with mass.

- The *description of motion* is referred to ***a frame of reference,*** a set of ***measurable parameters*** and their evolution in time. To explain *why a motion happens*, physics proceeds by identifying some ***basic principles,*** introducing some ***models*** and developing some ***theories***.

- To measure a parameter one needs to *define a unit* and *compare the parameter to that unit*. One may distinguish a minimum number of parameters that are *considered as basic* in the sense that the others can be *derived* from them by use of mathematical expressions. In the SI (international system) the basic parameters are *Length*, *Time*, *Mass* and the basic units are meter(*m*), second(s) and kilogram(*kg*).

- In general, the solution of a physics problem finishes by getting a mathematical expression for a physical parameter. One must verify if the expression makes sense by using the *dimensional analysis*.

- Some times the values of parameters that participate in an expression are not given in SI units. One has to convert all units in SI units before performing numerical calculations by using the expression.

- One prefers to use scientific notation when dealing with very small or very big numbers.

-When measuring a parameter there is always uncertainties. So, one can get only a *best estimation* of its real value. When reporting this estimation one knows that the *last digit* is *significant* (meaningful) but *not certain*. The *significant figure* of numerical value is equal to *number of significant digits* it contains. When using some measured parameters to calculate an expression, one must pay attention to the significant figure of the result. It cannot be better than the sig. fig. of parameters in the expression. So, its significant figure should be, at better case, *equal to the smallest significant figure* of entered values.

- Some typical relationships one uses often in physics are:

a) proportional ($y = kx$) and linear ($y = kx+c$)
b) parabolic ($y = ax^2$)
c) inverse ($y = a / x$ and $y = a / x^2$)
d) exponential ($y = y_0\, e^{b*x}$)