PHYSICS and CHEMISTRY

ESO 2

Antonio Ruiz Hernández

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PHYSICS and CHEMISTRY
ESO 2

Student's Book

Antonio Ruiz Hernández

educàlia
editorial

UNIT 1 SCIENTIFIC ACTIVITY

UNIT 2 MATTER PART I

UNIT 2 MATTER PART II

UNIT 3 THE CHANGES

UNIT 4 MOTION FORCES

UNIT 5 ENERGY

unit 1
SCIENTIFIC ACTIVITY

1. WHAT IS SCIENCE?

Science is a kind of organized and testable knowledge, which let scientists give a reliable prediction about a subject.

Generally speaking, there are three types of Science: Experimental, Social and Formal.

- ***Experimental sciences*** are focused on the study of the Universe. Its name comes from the fact that predictions are usually tested by means of experiments carried out in laboratories. Some examples of experimental sciences are Physics, Chemistry or Biology.

Physics and Chemistry study phenomena, i.e. natural facts, facts which occur in the real world.

  - Physics studies the processes in which there is not a change in composition (in a physical change we have the same substances after it).
  - Chemistry studies the processes in which there is a change in composition.

- ***Social sciences*** study different phenomena related to the Humanity, such as Geography, History or Psychology. Their predictions are also tested in different ways because socials scientists cannot perform experiments as experimental scientists do.
- ***Formal science*** is knowledge about abstract or non-real objects, such as numbers. Mathematics, Logic or Computer sciences are examples of Formal sciences.

EXERCISES

1. Classify the following sciences in accordance with the above explained classification: Mathematics, Geology, Psychology, Biology, Computer Science, History, Chemistry, Physics, Sociology, Logic, Astronomy, Geography

EXPERIMENTAL SCIENCES	SOCIAL SCIENCES	FORMAL SCIENCES

2. Classify the following phenomena in physical or chemical:

a) The falling of an apple.

b) The echo.

c) Evaporating water.

d) Oxidation of a nail.

e) Mixing bleach and ammonia.

f) Mixing salt and water

2. THE SCIENTIFIC METHOD

The scientific method is a procedure used by all the scientists since Galileo Galilei developed it in the 17th Century for the first time. These are the steps of this method:

A) Observation and asking a question

The main purpose of scientific observation is raising a question related to Nature. As a matter of fact, every scientific research is an attempt to give an answer to a certain question.

Example ([1]UB video): Why is that plant growing faster?

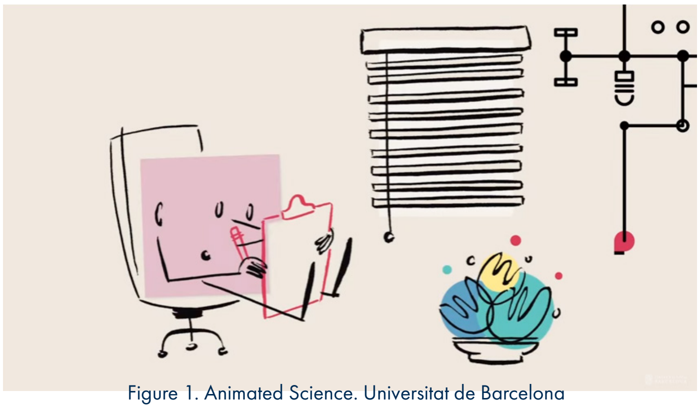


Figure 1. Animated Science. Universitat de Barcelona

B) Formulation of a hypothesis

A hypothesis is a conjecture, a statement or an explanation based on our previous knowledge of the Universe, which can explain some phenomena and be tested empirically.

Example (UB video):

- Hypothesis 1. The books are making the plant grow faster.
- Hypothesis 2. The music is making the plant grow faster.
- Hypothesis 3. The sunlight is making the plant grow faster.

C) Experimentation

A scientific hypothesis must be stated in terms of measurable quantities to let us check whether it is true or false. In other words, a hypothesis must give us a testable prediction so that we can know whether it is right or false after collecting the results of an experiment (or experiments).

Example (UB video):

- Experiment 1. We put one plant (control) without books near to it, and another plant (the variable) near to a pile of books.
- Experiment 2. We put one plant (control) in a silent place, and another plant (variable) near to music playing.
- Experiment 3. We put one plant in a dark place and the other one under a window where the sunlight can light it up.

D) Analysis

In this stage the scientist must check what is happening with the experimentation, analysing the results (tables, graphs...).

Example (UB video):

- Experiment 1. There is no significant difference between the two plants (control and variable).
- Experiment 2. There is no significant difference between the two plants (control and variable).
- Experiment 3. The plant under the sunlight grows significantly faster.

1 You can watch this video at http://physchem.tecnoruiz.es

E) Conclusion: Statement of laws and theories

After analysing the results of the experiments we may be able to draw a conclusion.

Example (UB video):

- Sunlight makes plants grow faster.

A scientific law is a statement which is verified empirically and has a universal applicability. Before you can say you discovered a scientific law many experiments must demonstrate it is right.

F) Dissemination

This is an important stage in modern Science. Scientists disseminate the results of their investigations publishing it in magazines, on the Internet... They can also read a lot of information about other scientists' works and that helps them to orient their research.

Figure 2. Scientific Method Poster (www.teachers-tools.com)

EXERCISES

3. Do you think that the conclusion of the example ("Sunlight makes plants grow faster") can be considered as a scientific law according to the method followed in the video?

4. According to the following observation, write down the rest of the steps of the Scientific Method you would follow.

Observation: "There's nothing on my smartphone screen".		
Question:		
Hypothesis: o H2: o H3: o H4:	Experiment: o E1: o E2: o E3: o E4:	Results/Analysis: o R/A1: o R/A2: o R/A3: o R/A4
Conclusion		
Dissemination:		

3. QUANTITIES AND UNITS. SI UNITS.

A **physical quantity** –or physical magnitude- is a physical property of a body or phenomenon, which can be measured quantitatively. The height of people can be known perfectly, so it is a physical quantity. On the other hand, beauty cannot be measured so easily, so it is not a physical quantity.

A **unit** is a value of a certain physical quantity, which is chosen by convention and used to fix the value of different quantities of the same kind.

Measuring a physical quantity is comparing its value with the proper value of the unit. For instance, you can use the length of your hand to measure another length. In this case your unit is your own hand and the value of the length is the number of times you have to place your hand from one point of a body to the opposite one.

It is very important to share the same units all over the world, so that people can trade, sell and buy products fairly. In the 19th century the General Conference on Weights and Measures established the **Metric System**, based on **3 units (metres, kilograms and seconds)**. **The International System of units (SI) was created in 1960** and is used by almost all countries.

There are two different kinds of physical quantities: base and derived.

On the one hand, a base quantity is easy to be measured and its unit can be defined universally in terms of a physical constant.

There are seven base quantities:

- **Length** is a quantity that measures the distance between two points. In SI its unit is the **metre**.
- **Mass** is related to the amount of matter of a system or body. In SI it is measured in **kilograms**.
- **Time** measures the duration between two events. In Si it is measured in **seconds.**
- **Temperature** quantifies how cold or hot a body is. In SI it is measured in **Kelvin (K)**.
- The **amount of substance** measures the number of particles (atoms or molecules) of a body. It is measured in **moles**, in SI.
- **Electric current** measures the flow of electric charges through a conductor and its unit is called **Ampere.**
- Finally, the **luminous intensity** measures intensity of light in **candelas.**

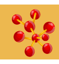
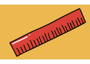
Physical quantity measured	Base unit	SI abbrevation
	mole	mol
	meter	m
	kilogram	kg
	second	s
	Kelvin	k
	ampere	A
	candela	cd

Figure 3. Seven SI basic units of measurement

On the other hand, **derived quantities** can be set in terms of the fundamental ones, so we don't need to define a specific unit for them. For instance, length is a fundamental quantity, which can be measured very easily, but area is a derived quantity because we can find its value with a formula. You can see some examples:

Derived Quantity	Name	Symbol
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second squared	m/s^2
mass density	kilogram per cubic meter	kg/m^3

Some units may not be adequate to measure great or little quantities. Example: to measure the mass of a pencil the kilogram is not used. In those cases, these prefixes can be used (multiples and submultiples):

Multiplier	Exponent form	Prefix	SI Symbol
1 000 000 000 000	10^{12}	tera	T
1 000 000 000	10^{9}	giga	G
1 000 000	10^{6}	mega	M
1 000	10^{3}	kilo	k
100	10^{2}	hecto	h
10	10^{1}	deca	da
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	mili	m
0.000 001	10^{-6}	micro	µ
0.000 000 001	10^{-9}	nano	n
0.000 000 000 001	10^{-12}	pico	p

REMEMBER

A physical quantity must include:

NUMBER + UNIT

EXERCISES

5. Complete the following table, indicating the type of quantity and the SI units used to measure each one

QUANTITY	TYPE	SI Units
Density	*Derived*	*kg/m^3*
Volume		
Length		
Force		
Mass		
Time		
Speed		

3.1. CONVERSION OF UNITS.

Sometimes we get a physical quantity with a certain unit and we need to change it to an International System (SI) unit.

For **Base Quantities (revision):**

A. Linear quantities (e.g. metres):

To go up move the decimal point one position to the left (or add a zero on the left).

Ex: 100 m = 10 dam = 1 hm

- To go down move the decimal point one position to the right (or add a zero on the right).

  Ex: 1 m = 10 dm = 100 cm

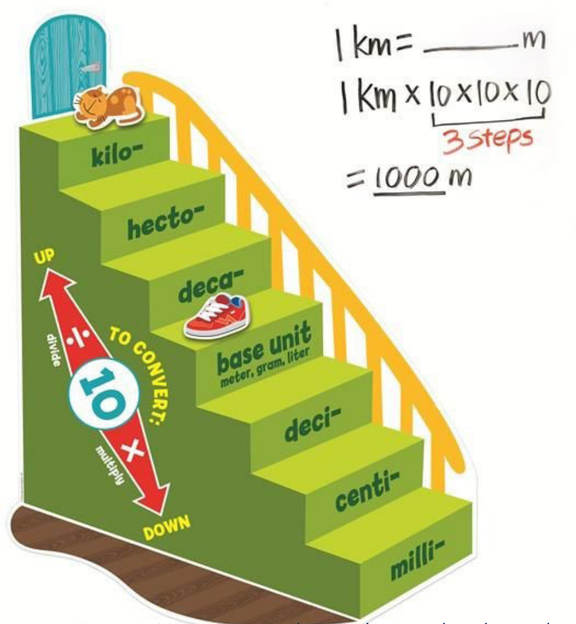


Figure 5. Magnetic Metric Staircase (www.educationalinsights.com)

B. Quadratic quantities (e.g. m²):

- To go up a step move the decimal point two positions to the left (or add zeros on the left).

  Ex: 100 m^2 = 1 dam^2 = 0.01 hm^2

- To go down a step move the decimal point two positions to the right (or add zeros on the right).

  Ex: 1 m^2 = 100 dm^2 = 10000 cm^2

C. Cubic quantities (e.g. m³):

- To go up a step move the decimal point three positions to the left (or add zeros on the left).

  Ex: 1000 m^3 = 1 dam^3 = 0.001 hm^3

- To go down a step move the decimal point three positions to the right (or add zeros on the right).

  Ex: 1 m^3 = 1000 dm^3 = 1000000 cm^3

EXERCISE

6. Change these units to the different ones in brackets, using conversion factors.

a. 2.5 km (cm)

b. 3 ml (l)

c. 55 cm^3 (m^3)

d. 1 m^3 (dm^3)

e. 3 μm (mm)

f. 15 m^2 (cm^2)

g. 15 h (s)

For **Derived Quantities**:

A **conversion** factor is a fraction which has the same amount at its numerator and denominator, but measured in different units. Conversion factors let us change a physical quantity to a different unit without changing its amount. They can be used also to convert Base Quantities, but it is easier using the "ladder method" explained above.

Examples:

20 ***m/s*** ---- How to convert to ***km/h***?

$$20\,\frac{m}{s} = 20\,\frac{m}{s}\cdot\frac{1\ km}{1000\ m} = 0.02\,\frac{km}{s}\cdot\frac{3600\ s}{1\ h} = 72\,\frac{km}{h}$$

300 ***mg/dm***^{3} ---- How to convert to ***g/cm***^{3}**?**

$$300\,\frac{mg}{dm^3} = 300\,\frac{mg}{dm^3}\cdot\frac{1\ g}{1000\ mg} = 0.3\,\frac{g}{dm^3}\cdot\frac{1\ dm^3}{1000\ cm^3} = 0.0003\,\frac{g}{cm^3}$$

Note:
1 t = 1000 kg

EXERCISE

7. Change these units to the different ones in brackets, using conversion factors.

A. 55 cm^3 (m^3)

B. 120 m^2 (cm^2)

C. 15 m/s (km/h)

D. 3.6 g/cm^3 (kg/m^3)

E. 300 m^3/h (dm^3/s)

F. 700 t/h (kg/s)

G. 70 km/h (m/s)

H. 12 t/m^3 (kg/cm^3)

4. SCIENTIFIC NOTATION.

In science, we deal with some very LARGE numbers:

1 mole = 602000000000000000000000 atoms (or molecules)

In science, we also deal with some very small numbers:

Mass of an electron = 0.00000000000000000000000000000091 kg

Imagine the difficulty of calculating the mass of 1 mole of electrons!

0.00000000000000000000000000000091

x 602000000000000000000000

??

Working with such numbers is much easier using scientific notation. Scientific notation is a method of representing very large or very small numbers in the form

$M \times 10^n$

- M is a number between 1 and 10 $(1 \le M < 10)$
- n is an integer

Example: 2 500 000 000 would be $2.5 \cdot 10^9$

Example: $63.4 \cdot 10^{-9}$ is not well written in scientific notation.

Example: $6.34 \cdot 10^{-8}$ is well written in scientific notation.

Example: $0.634 \cdot 10^{-7}$ is not well written in scientific notation.

But, how do we convert a standard number to scientific notation? To convert a number to scientific notation, we count the number of places the comma is moved to have an adequate value for M (between 1 and 10). X is the number of places.

a) If you moved to the left, X must be added (+) to the exponent.

b) If you moved to the right, X must be taken away (-) to the exponent.

Examples:

$4530000 = 4.53 \cdot 10^6$

$0.0007281 = 7.281 \cdot 10^{-4}$

EXERCISE

8. Calculate the corresponding values in scientific notation

STANDARD NOTATION	SCIENTIFIC NOTATION
39500	
0.073	
12	
43000000	
7	
1000000000000	
0.00002413	
104	
$0.0007 \cdot 10^8$	
$36.21 \cdot 10^5$	

9. Calculate the corresponding values in standard notation.

STANDARD NOTATION	SCIENTIFIC NOTATION
	$3.6 \cdot 10^5$
	$1.8 \cdot 10^{-3}$
	$8.48 \cdot 10^9$

5. THE LANGUAGE OF SCIENCE.

To communicate the results of any scientific research scientists use a very accurate language, including physic equations, data tables and graphs.

5.1 PHYSIC EQUATIONS

A physic equation is a mathematical expression that relates physical quantities. For example, velocity is defined as the space travelled by an object in a certain period of time:

$$\mathbf{v} = \frac{\mathbf{s}}{\mathbf{t}}$$

Equations help us calculate quantities as the velocity of an object, but they are also useful to find out the relation between two quantities. Two of the most common relations between quantities are direct proportionality and inverse proportionality.

Two quantities are **directly proportional** when multiplying one by one number the other goes multiplied by the same number.

Two quantities are **inversely proportional** when multiplying one of the quantities by one number the other is divided by that number.

According to that definitions, *velocity (v) is directly proportional to space(s), whereas is inversely proportional to time (t).*

EXERCISE

10. According to the following equation:

$$P = \frac{F}{S}$$

a) What is the relation between P and S?

b) What is the relation between P and F?

5.2. TABLES AND GRAPHS.

Graphic representation is another way of analysing numerical data. Graphs enable us studying the cause and effect relationship between two quantities. Graphs help to measure the extent of change in one variable when another variable changes by a certain amount.

To draw a graph we need a set of data. In science it is common to gather the results of an experiment in data tables like this one:

STUDY OF THE ELONGATION OF A SPRING	
m (kg)	Δl (cm)
0	0
1	3
2	6
3	9
4	12
5	15

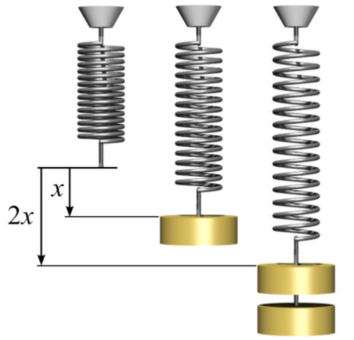
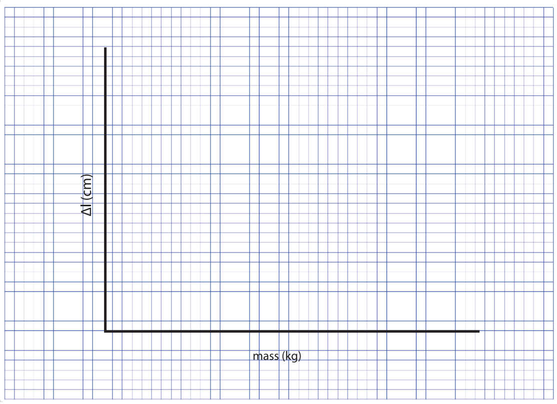


Figure 6. Elongation of a spring (Svjo - Wikipedia)

We are going to use that **data table,** which comes from the experimental study of the elongation of a spring with different weights, to illustrate the process of creating a graph.

To start drawing a graph you need to count on graph paper (squared). Then you have to follow these steps:

Step 1: Draw two perpendicular axes. The horizontal axis (X) will be used for the independent variable (the one we control and change in an experiment). The vertical axis will be for the dependent variable. You write down the name and unit of each variable beside each axis.

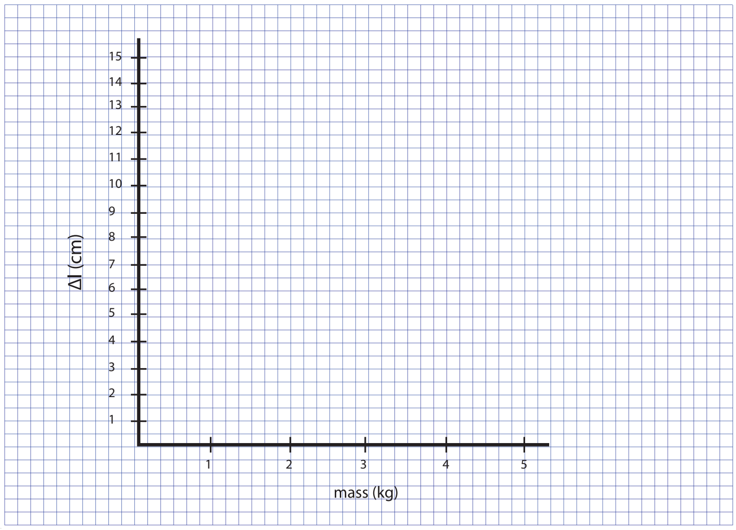


Step 2: Find the range in values. There are two sets of values. What units are used? What are the greatest value and the least value for the first set? What are the greatest value and the least value for the second set? In our examples the quantities are mass and elongation. The mass ranges from 0 to 5 and the elongation ranges from 0 to 15.

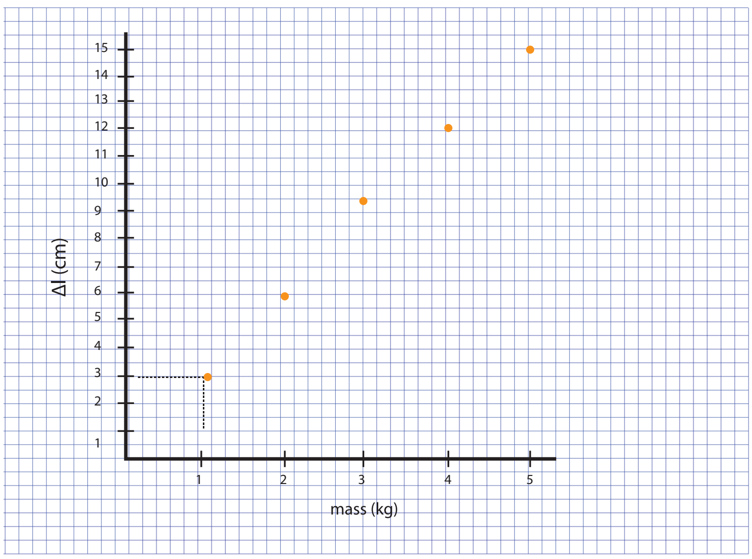
Step 3: Determine a Scale and draw the units on both axis. Start with the horizontal scale. In our example we have 30 squares available in the horizontal axis, and the mass starts with 0 and gets to 5 kg, so we could make 6 squares equal 1 kg, to maximise the use of the graph paper.

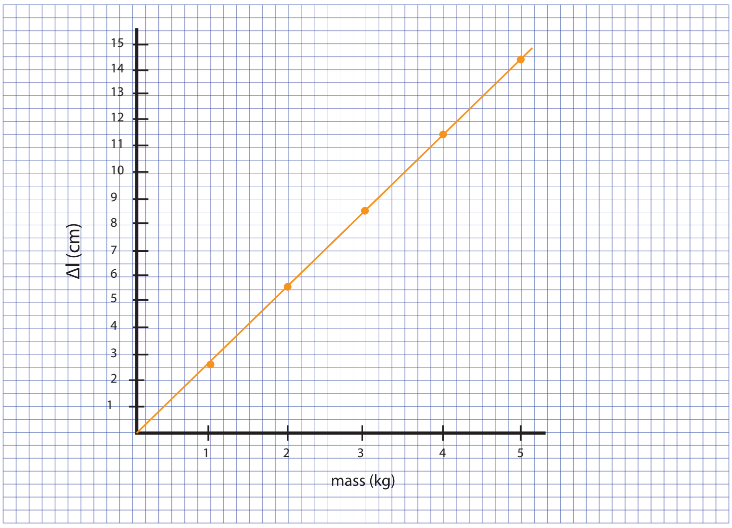
The vertical scale must always start at 0 (this is very important, and your teacher will let you know why). Consequently, in our example graph the vertical scale will range from 0 to 15. In the vertical axis we have 30 squares and the highest value is 15 cm, so we could make each two square equal 1cm.

Important: *Each axis can have its own divisions, but once you have decided how many squares equal a certain value, it has to be the same for the rest of the values for that axis*

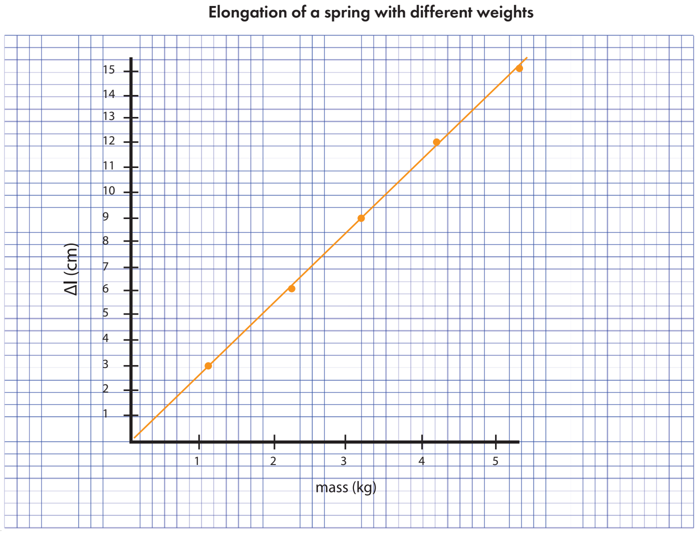


Step 4: Plot the points and connect them. Plot a point for each pair of values. Which item of a pair is indicated by the horizontal scale? And by the vertical scale? How many points will you plot? Connect the points with straight lines from left to right.





Step 5: Give the graph a title. What is your graph about?



When two variables are directly proportional, we get a graphic like this one. When the independent variable (mass) increases the dependent variable (elongation) increases by the same rate. If we represented inversely proportional quantities, the graph would be like the one in figure 7.:

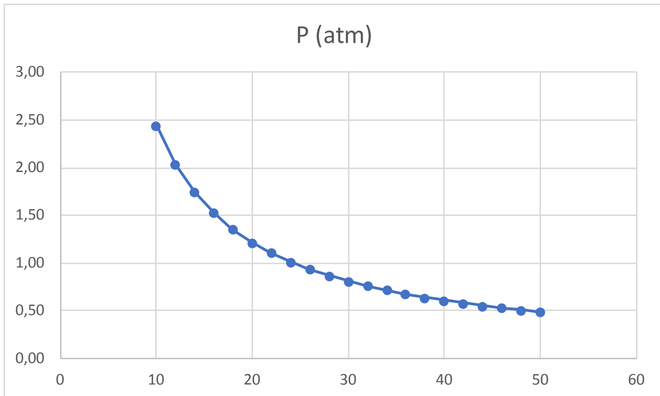


Figure 7. Pressure vs Volume

To sum up, the procedure for constructing a line graph follows these steps:

- Step 1: Draw two perpendicular axes.
- Step 2: Find the range in values.
- Step 3: Determine a Scale and draw the units on both axis.
- Step 4: Plot the points and connect them.
- Step 5: Give the graph a title

EXERCISE

11. In 2000, a law was passed against the use of cell phones while driving in Anytown, N.Y. The number of people who use cell phones while driving in Anytown has changed each year since then as shown in the table below. Construct a line graph to visually display this data.

Cell Phone Use While Driving in Anytown, NY	
Year	Number of People
2000	309
2001	274
2002	256
2003	238
2004	197
2005	203
2006	195
2007	192

12. Measuring the volume occupied by a fragment of a mineral according to its mass we get this set of values

m(g)	10	20	30	40	50
V(mL)	4	8	12	16	20

REVISION EXERCISES

1. Change these units to the different ones in brackets, using conversion factors when necessary

28kg (g)
3cg (hg)
324500mg (kg)
0.65 dag (mg)
320 cm (m)
755 m (hm)
2.5 dam (cm)
150 mL (hL)
33 cL (mL)
750 dL (cL)
150 min (s)
10800 s (h)
20.25m^2 (dm^2)
136.g/cm^3 (kg/dm^3)
1850.2cm^2 (m^2)
0.35km^2 (dam^2)
65g (μg)
65dm^3 (L)
50m^3 (dm^3)
0.3dm^3 (mL)
30ºC (K)
143K (ºC)
-45ºC (K)
90m/S (km/h)
540km/h (m/s)
4.2km/min (m/h)
200cm/s (m/min)

2. Change these units to SI units, using conversion factors when necessary.

a. 300000 km/s
b. 75 g/cm^3
c. 108000 km/h
d. 6.2 μg
e. 6.2 mm/min
f. 6700 mg/cm
g. 1.6 g/cm^3
h. 120 cm/min
i. 4285 mm/h
j. 450 mg/mm^2
k. 1.2 hg/dm^3
l. 1224 km/h
m. 6 mg/dm2
n. 485 dag/L
o. 540 m/h

3. Convert these values to scientific notation.

a. 1001
b. 0.13592
c. 53
d. 0.0038
e. 6926300000
f. 0.00000013
g. 3920000
h. 0.567
i. 0.00361

4. Convert these values to standard notation

a. $1.92 \cdot 10^3$
b. $1.03 \cdot 10^{-2}$
c. $3.051 \cdot 10^1$
d. $8.862 \cdot 10^{-1}$
e. $4.29 \cdot 10^2$
f. $9.512 \cdot 10^{-8}$
g. $6.251 \cdot 10^9$
h. $6.5 \cdot 10^{-3}$
i. $8.317 \cdot 10^6$

5. In the following table you have the data of the solubility of Oxygen (O_2) in water at different temperatures.

a. Draw the graph corresponding to these data (in your notebook, use a whole page in vertical orientation).

b. How does the solubility of O_2 in water vary with temperature? What is the relation between these two magnitudes?

c. How could affect the action of the sunlight in the summer to the aquatic life in a pond?

Temperature (ºC)	Solubility (µg/ 100g)
0	1420
5	1230
10	1090
15	980
20	880
25	810
30	750
35	700

6. Studying the motion of an object the following data are obtained

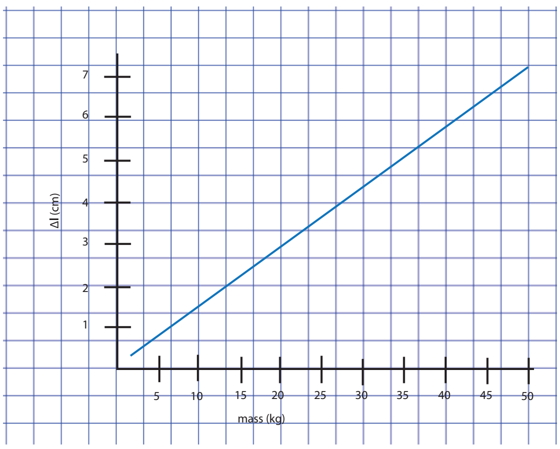
Position (cm)	4	16.5	24	29	54
Time (s)	0	5	8	10	20

a) Represent the graph of Position vs. Time.

b) Point out, in the graph, the Time that corresponds to the Position 40 cm.

c) Find out, extrapolating, the position that would correspond to the Time 22s

7. We hang different weights from a spring, getting different elongations according to this graph:



a. What is the relation between mass and elongation?

b. What would be the elongation for 20 kg?

c. What weight do we need to get an elongation of 60 cm?