The University of Crete
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Science Experiments with Self-Made Equipment(*)

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Literacy in Science and Technology (STL)
is fundamental for the welfare of modern, technology dependent societies

STL constitutes a prerequisite to and a right to Democracy

As more and more of the regulations of modern, technology dependent societies are based on the advances in Science and Technology, the basic constituent of democracy, i.e. citizens' participation, requires STL.
See also UNESCO

➔Science Teaching in General Education (especially in compulsory education):

should be based on principles and methodology rather than on factual knowledge

poses specific demands on the skills and knowledge of the Science Teacher

Within a Piagetian context, Science knowledge is not acquired by the student but it is discovered or, at least, negotiated anew.

This teaching approach is
heavily dependent on systematic Science observations and experiments and this makes experimentation a basic required skill of the Science teacher.

Teachers' attitude towards Science

Should change from factual knowledge on specific data, techniques and themes or from the "successful performance" of an experiment, towards a "scientific inquiry" approach

Lillian C McDermott, Peter S Shaffer and C P Constantinou, "Preparing teachers to teach physics and physical science by inquiry", Phys. Educ. 35(6) November 2000, pp. 411-420

Science Teacher: should possess a sound knowledge of the basic principles

➔Science Teachers' education a crucial parameter

P. G. Michaelides, An affordable and efficient in-service training scheme for the Science Teacher, "Sixth International Conference on Computer Based Learning in Science 2003 (CBLIS03), University of Cyprus, Nicosia, Cyprus, 5 - 10 July 2003" proceedings pp. 792-799.

Science Teacher's education should include:

A.-Education in Science and in Science Teaching for the Teacher him (her) self

→ Polymorphic Teaching

P. G. Michaelides, "Polymorphic Practice in Science", pp 399-405 of the proceedings of the 1st Pan-Hellenic Conference on the Didactics of Science and the introduction of New Technologies in Education, University of Thessaloniki, Thessaloniki May 29-31, 1998 (in Greek).

B.-Education – Training on the school Science curriculum especially:

on practice work and on relating Science to everyday observations

P. G. Michaelides, "Everyday observations in relation to Natural Sciences" in Learning in Mathematics and Science and Educational Technology, University of Cyprus July 2001, Volume II pp. 281- 300.

Polymorphic Teaching

Polymorphic practice (measurements, experiments...) in Science:

Includes a psycho motive activity (doing measurements, experimentation...)

which consequently is morphed into different levels

depending on the (previous) cognitive attainment and/or the mentality of the students.

Resemble Multilevel Teaching

i.e. teaching pursuing more than one sectors and levels of learning.

The need for polymorphic practice teaching arises usually

in the training of Science Teachers where:

there is a requirement of teaching in an advanced level for the teachers themselves, and,

a requirement of teaching in a level more accessible for the pupils.

The difference in the teaching levels is

not only on the didactics but also on the subject matter and the attainment levels.

Sophisticated complex equipment may:

Give accurate measurements,

Be necessary in quite a few times.

However:

It hinders the principles under study

in the effort of understanding how to use the equipment.

Converts the experiment to a demonstration process

in which the student observes the results of an apparatus he-she does not understand

It removes the authentic creative activity,

get the results of the experiments instead of inquiring a Natural phenomenon.

Science teachers lack, in general, the skill

to transform their scientific knowledge into teaching practice.

➔Science and Technology are considered as difficult subjects,

although they are rather simpler and possess inherent teaching advantages.

Science subjects of study are easily perceptible through the senses, an irrefutable advantage for most of the compulsory education students who, in a Piagetian context, have not as yet reached the formal logic stage.

Inefficiency of Science Teaching
constitutes a significant problem in the technology advanced countries.

Practice work in compulsory education Science Teaching
may be improved with the use of self-made apparatus.

Piaget ("the future of Education") assigns this difficulty in relation to Science while students are performing well in the rest of the subjects to the type of instruction offered with a more probable cause the fast passage from the qualitative management of natural problems to the quantitative mathematization through the use of Physical Laws that enter the instruction in the student's absentia.

Self-made apparatus to be used in classroom Science experiments:

is a very creative process

associated with the development of cognitive and psycho motive skills

and facilitates the logical process of induction.

facilitates the development of social skills (in a group work construction),

covers the sentimental sector the "pleasure of creation".

Other inherent advantages of self-made apparatus:

- facilitates query situations and the process of planning an experiment;
- demonstrates an immediate application of some of the relevant Science issues;
- removes the "black box" feeling associated with the use of hi-tech devices;
- it develops the ingenuity of the teacher for alternatives to expensive equipment;

- easily diferentiation between observations' data and their interpretation.

P. G. Michaelides, "Understanding difficulties in Science observations", oral presentation, 2nd Pan-Hellenic Conference on the Didactics of Science and the introduction of New Technologies in Education, University of Cyprus, Nicosia May 3-5, 2000 , book of abstracts page 26 (in Greek).

Discrimination between observations – data and interpretation - theory

How do we discriminate between electric (i.e. electrostatic and magnetic forces?

- **in both cases we observe attraction or repulsion**
- **are there any observable differences?** **(e.g. magnetic force exist in specific only materials? does it have a different magnitude? May coexist with electrostatic force? etc).**

'what do we observe when we leave a body to fall?'

- **we observe that Earth attracts the body and the body falls.**
- **we observe that the body falls.**
- **we observe that the body moves towards the earth.**

Which answers are correct – wrong? Why? Can you invent another interpretation instead of the gravitational attraction?

'what do we observe when the switch is closed?

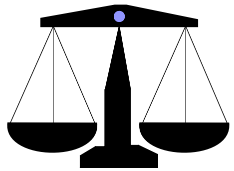
- **we observe electric current flows through the circuit.**
- **we observe that the bulb lights.**

Why the answers above are right or wrong?

If the bulb does not light is there a flow of electric current?

Differentiation between the quantities actually measured and the assigned ones.

what quantity is measured – to what quantity the measurement is assigned to – under what conditions (theory). e.g.:



what do we measure with a balance what with a spring balance??

The statement: the balance measures mass the spring balance measures weight' is it correct?

Balance: comparison of moments by measuring deviations from the 'horizontal'

→ Comparison of forces, i.e. of weights

→(same gravitational field) comparison of masses.

Spring balance (dynamometer): measurement of elongation → (Hooke's law) Force i.e. weight.

Accuracy and Sensitivity of measurement vs. measurement error.

- **Measurement error** (often an unknown concept)

  limits, estimation of measurement errors – treatment of random and systematic errors

- **accuracy of measurement** – often confused with the error
- **sensitivity of measurement**

both are often confused with the measurement error

‘Objective’ vs. Biased experiments.

examples:

- **‘linear propagation of light’** **(only under certain conditions)** **but linearity using our eyes**
- **free fall of bodies follow the vertical but verticality by plumb line (pendulum)**
- **vertical does not pass through the earth’s centre (what is meant by this?)**
- **irrigated plants grow up more** **(not valid always)**

  without due regard to other parameters **(e.g. ventilation, sun – light, soil, fertilization, …)**

Incorporated into the education of the Science Teacher,

The construction of self-made apparatus for Science experiments:

- **is another example of polymorphic practice**
- **facilitates the transformation of scientific knowledge to school practice.**

In this presentation:

The use of self-made apparatus in Science teaching experiments is discussed.

(Polymorphic) Examples from different areas of Physics are presented.

In order to be useful to Science Teaching

The construction of self-made apparatus must follow some principles,

in accordance to the context exposed previously, i.e.:

- →Simplicity and Safety
- →Problem solving
- →Accuracy, sensitivity and calibration
- →Assessment

Simple construction
with easily available materials from the environment of the school and the students.

Feasibility of assembly within the abilities of a “do it yourself layman”.

An (optional) objective the dexterities and knowledge
on the properties of the materials used and on how to handle them.

Simple constructions:
facilitate the understanding on the apparatus functioning
minimize safety problems.

Safety is always an important issue that must be stressed, even over emphasized:
to students (especially children) involved
to teachers (especially Primary School Science Teachers)
who, in general, lack a professional training in Science.

Development of good safety awareness attitudes.

Problem solving

Principles (continued)

The construction process

must provoke the ingenuity and creativeness of the students.

The guidance offered must:

remain within the above general goal,

Leave the initiative to the student.

Detailed guidance should be limited to specific queries

related to technical or specialized issues.

The prime goal is to understand the principles ("natural law") involved
➔high levels of accuracy are not required.

Adequate Accuracy and Sensitivity must be present
if the apparatus constructed is used as a measuring instrument.

Calibration is a necessary step for apparatus used as measuring instruments.

Usually calibration is done by comparison with a professional instrument but
A discussion on the principles used to make measuring standards **is enlightening.**

Estimation of the **accuracy and errors** helps
on the conceptual meaning of measuring errors and their treatment.

When the construction is finished,

It is advised to perform:

a retrospective evaluation

on the whole process,

on the choices made

on the other possible alternatives,

a comparison to apparatuses made by others

It recapitulates on the subject under study and facilitates meta-cognitive effects.

Aesthetics of the final construction is an important issue

Showing practicality and an indication of deliberation and diligence.

although it is highly subjective.

All have been realized
in the Department of Primary Education of the University of Crete
within the normal teaching activities in Science.

They include:

Measurement of the wavelength of light
A Gas Thermometer
A Hydrometer
A weighing-machine
An amperometer
Electric motor
Mechanical resonance
Geographical coordinates
Bernoulli's Law

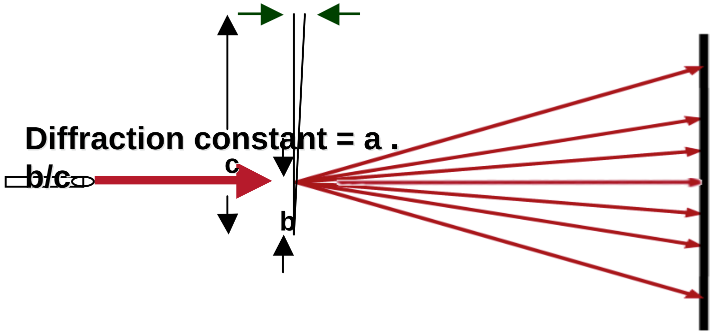
etc

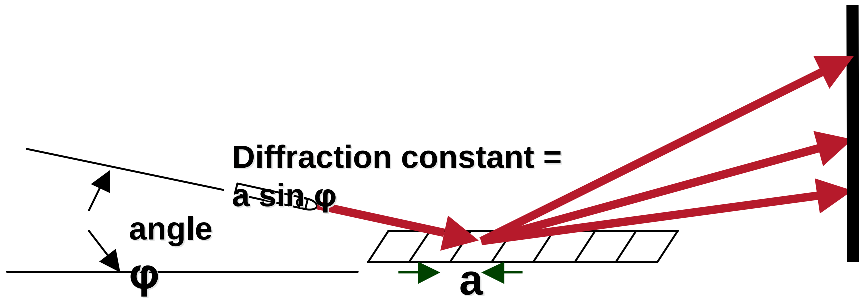
Problem solving (an example)

Measurement of the wavelength of light usually done with a diffraction grating, but:

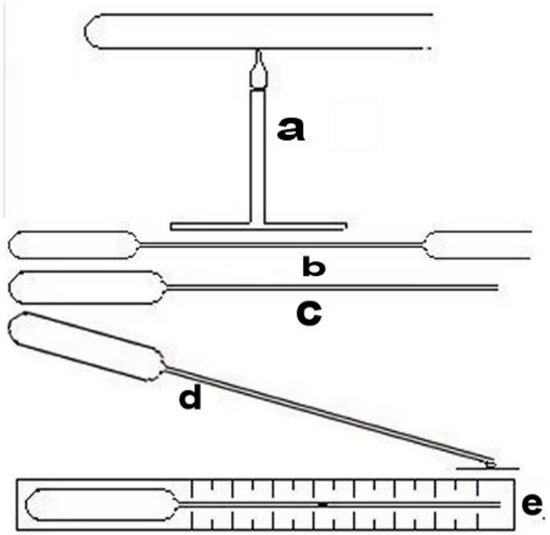
see two different ways to measure it with simple means

also see it as an example to apply known and simple mathematics





Gas Thermometer



The task is to construct a thermometer.

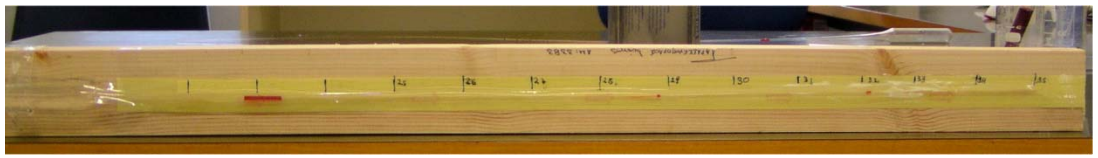
Objectives may include (on top of the subject matter):

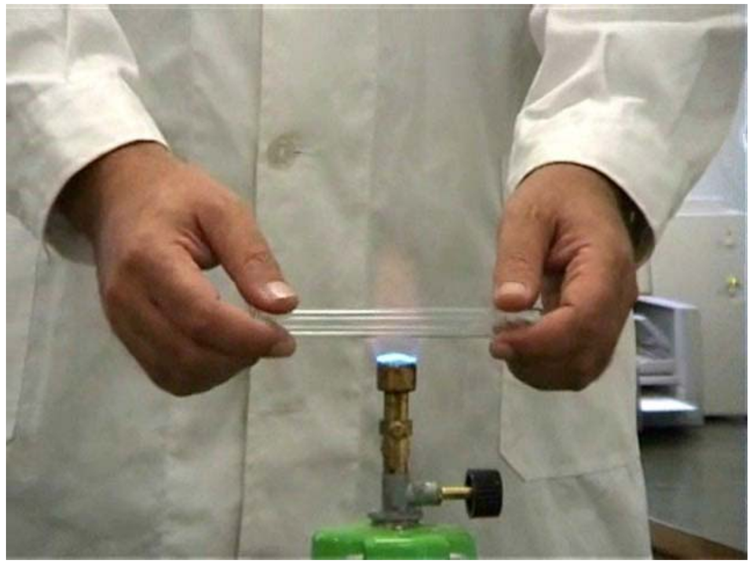
basics on glass treatment,

a useful skill for chemistry experiments,

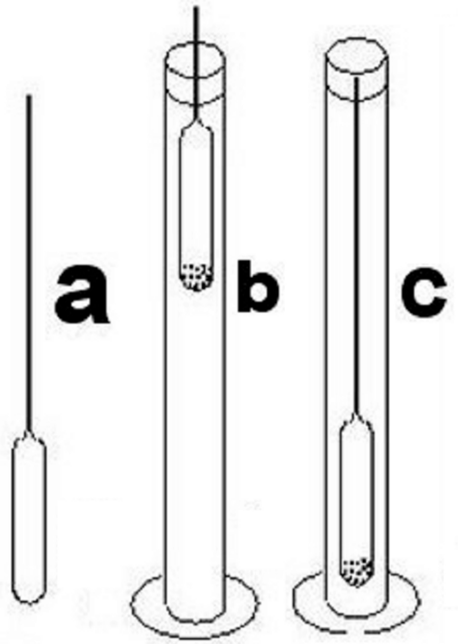
notions of calibration, accuracy and sensitivity, error.

The device may be used also as a dropper, a hydrometer, etc.





Hydrometer **Some examples** **(continued)**



The task is to construct a Hydrometer.

To measure the density of liquids

Objectives similar to those of the Gas Thermometer.

Construction as in the Gas Thermometer

the elongated pipe should not be too thin;

Put into the small lead balls (e.g. thin shot) or sand;

Immerse it into liquids of different densities

in b – a relatively dense liquid

in c - a relatively thin liquid

Fix the device into a cardboard with the scale

Seal the open end of the elongated pipe.

Calibration is done by preparing liquids with a known density

Salt into water – alcohol and water, etc

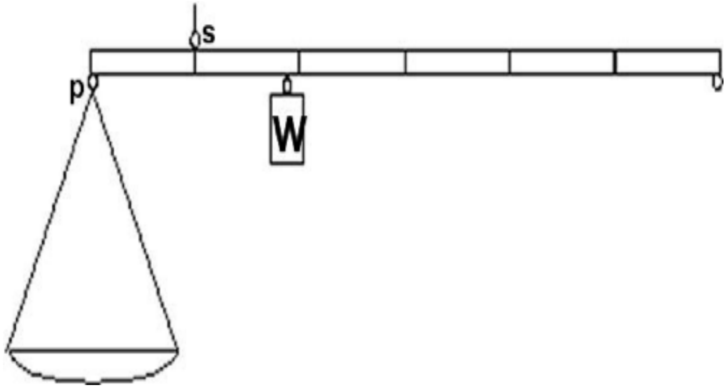
Used to measure the density of wines and spirits ("infer" the alcoholic content).

Advantageous to the understanding

of density, of the different ways of titration of solutions, etc.

A weighing-machine

Some examples (continued)



The task is to construct a Weighing machine.

Objectives mechanical moments:

In the Calibration process

mechanical moments may be clarified.

Made with materials used to hang slide curtains in house windows.

The weight, W, hangs from a hook used to hold the curtain within the slide rod.

Similar hooks are used for the joints in p and s.

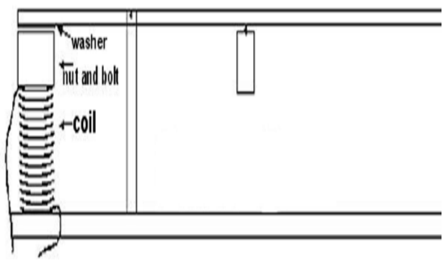
The construction, if done with diligence, may be very accurate.

It is also used in other apparatus (see for example "An amperometer" later on).

An amperometer

An amperometer (continued) **Some examples (continued)**

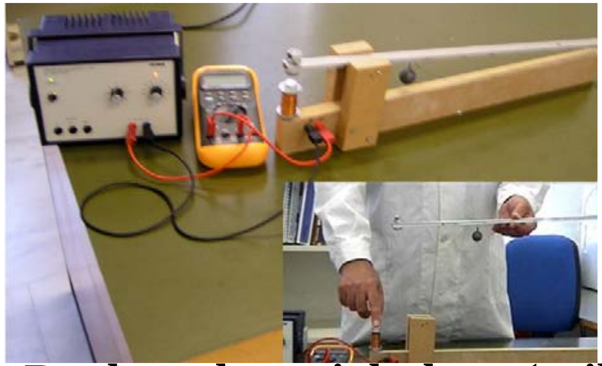
Objectives **electromagnetic forces:**



Construction based on the weighing machine.

The plate is replaced by an iron washer fixed on the balance rod and a coil around an iron bolt.

Connecting the coil serially to an electric circuit, an electromagnetic force is induced which holds the washer to the bolt.



Moving the weight along the rod the electromagnetic force may be measured comparing the mechanical moments.

An adaptation:

Replace the weight by a (coil) spring. Fix the bolt in the place of the washer.

Increase the height of the rod supporting the balance rod.

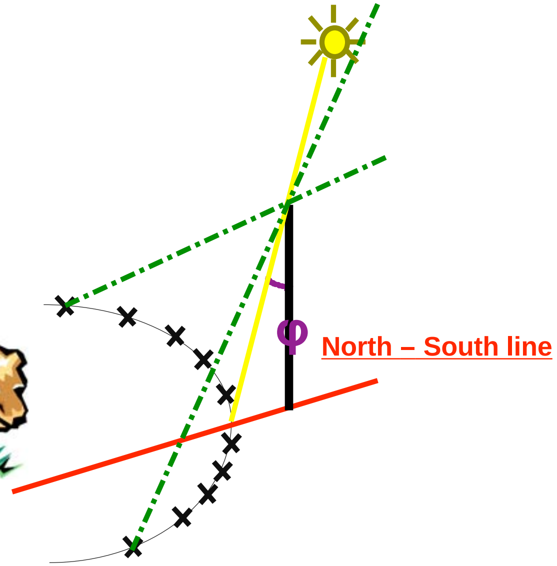
When the electromagnet is activated the bolt is attracted into the (hollow) coil and the corresponding force may be measured by the elongation of the spring.

Fixing the spring in different distances from the supporting the balance joint, different current ranges may be measured.

A fiction story

A scientific expedition was taking the measurements of the shadow of a vertical rod when a just awakened bear attacked them.

What colour was the bear?



A TV Commercial.

Saloon in the middle of nowhere at dusk. A cowboy strikes a match to light a cigar when, far in the horizon, one light catches his attention. He freezes staring it and sometime later a car (vroom, vroom, vroooo…m) passes while at this time the match burns his finger.

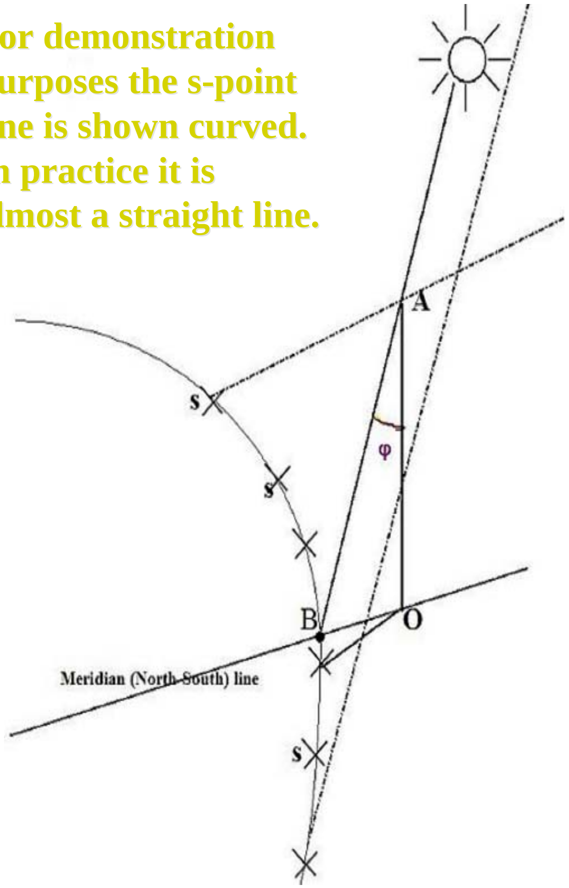
What was the speed of the car?

An Observation.

You are in an airplane that is preparing to land.

Can you estimate the landing speed of the airplane?

For demonstration purposes the s-point line is shown curved. In practice it is almost a straight line.



Objectives earth's movements – handling of errors:

Construction:

a simple vertical rod OA on a flat horizontal surface.

We mark the end of the shadow of the rod (s points) together with the time and draw the (~straight) line.

Smallest distance OB is the local meridian.

The time for the shadow in OB is the local noon.

It determines the Longitude of the place.

The angle φ is related to the local Latitude.
It is equal to the Latitude on the equinoxes (21st of March and 23rd of September).
On the solstices, φ = Local latitude ± e, e ~23.5 arc degrees is the obliquity of the ecliptic.

The angle φ versus the day of the year is periodic with extremes at the solstices.

May be used also to determine the seasons, the equinoxes and the solstices (23rd of December and 21st of June)

Presentations, e.g. diagrams

➢what quantities are represented

(a conceptual problem for distance)

➢smoothing

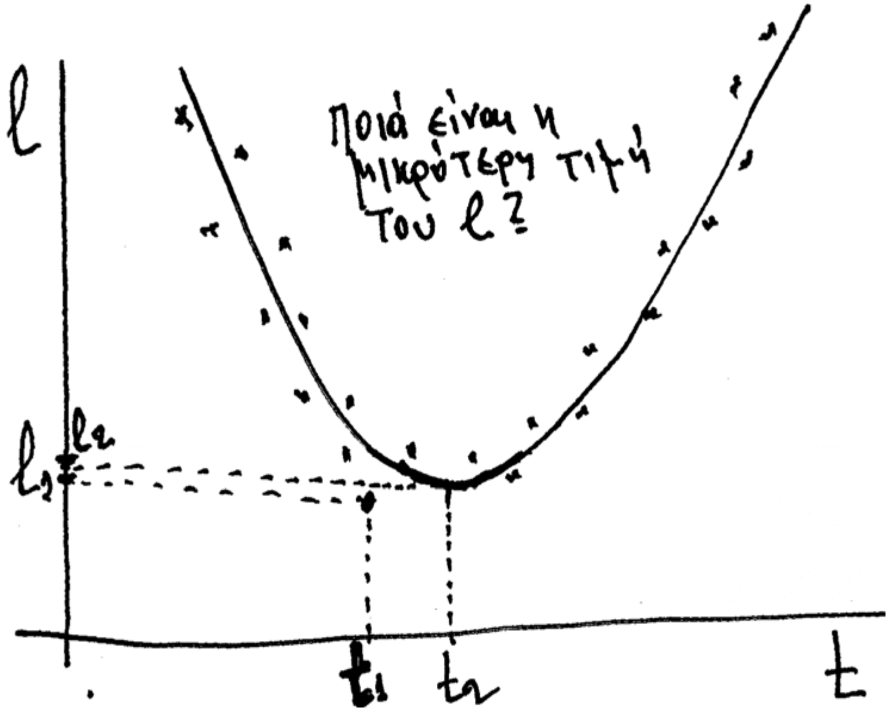
('in textbooks all points fall on the lines')

➢Choice of scales

- form (linear, log, ….)
- size of the diagram (readability)
- detail - formal accuracy,
- usability of scales,
- range.

➢Use of the diagrams,

Instead of the original measurements, e.g. →

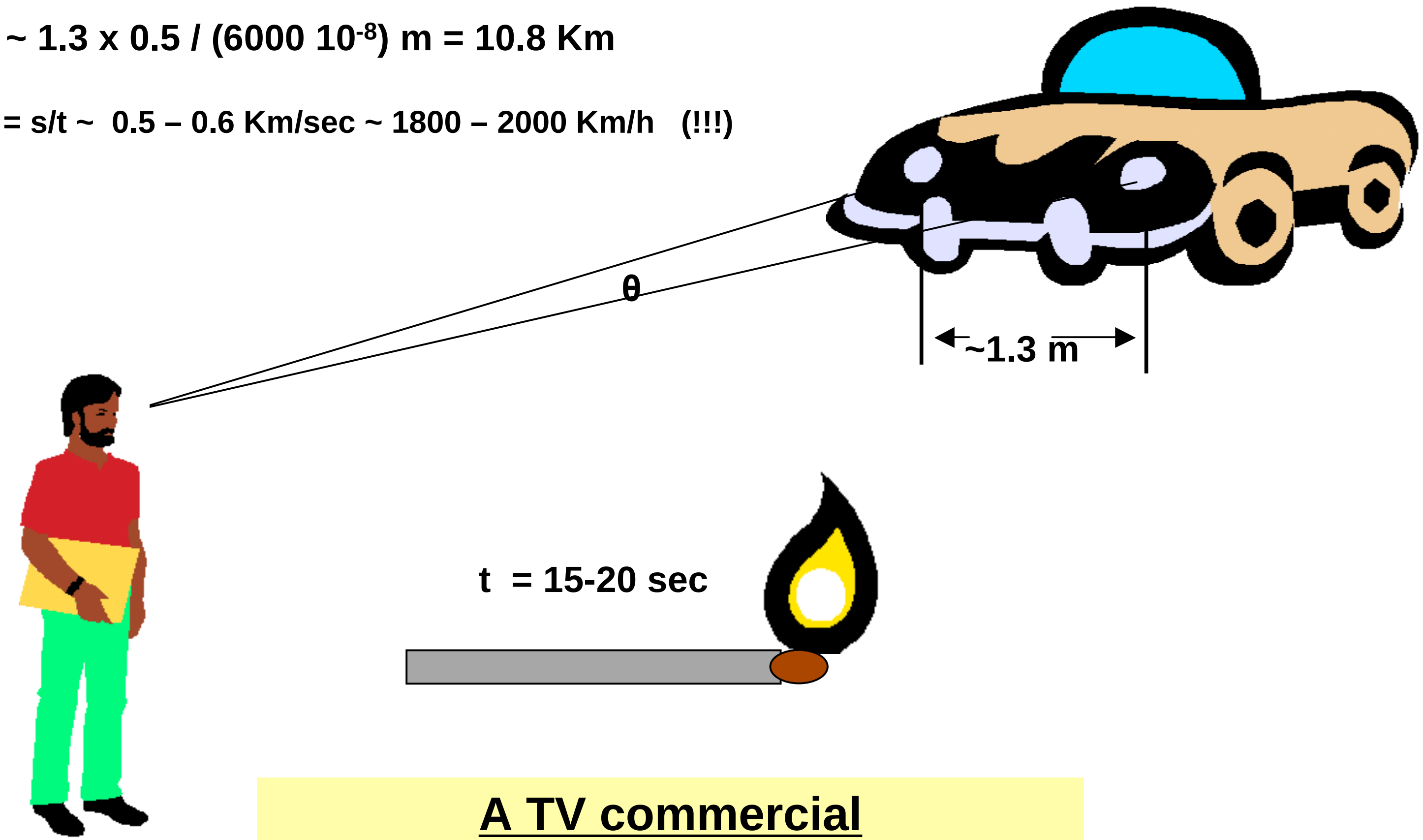


$\underline{\theta >= \lambda/D}$

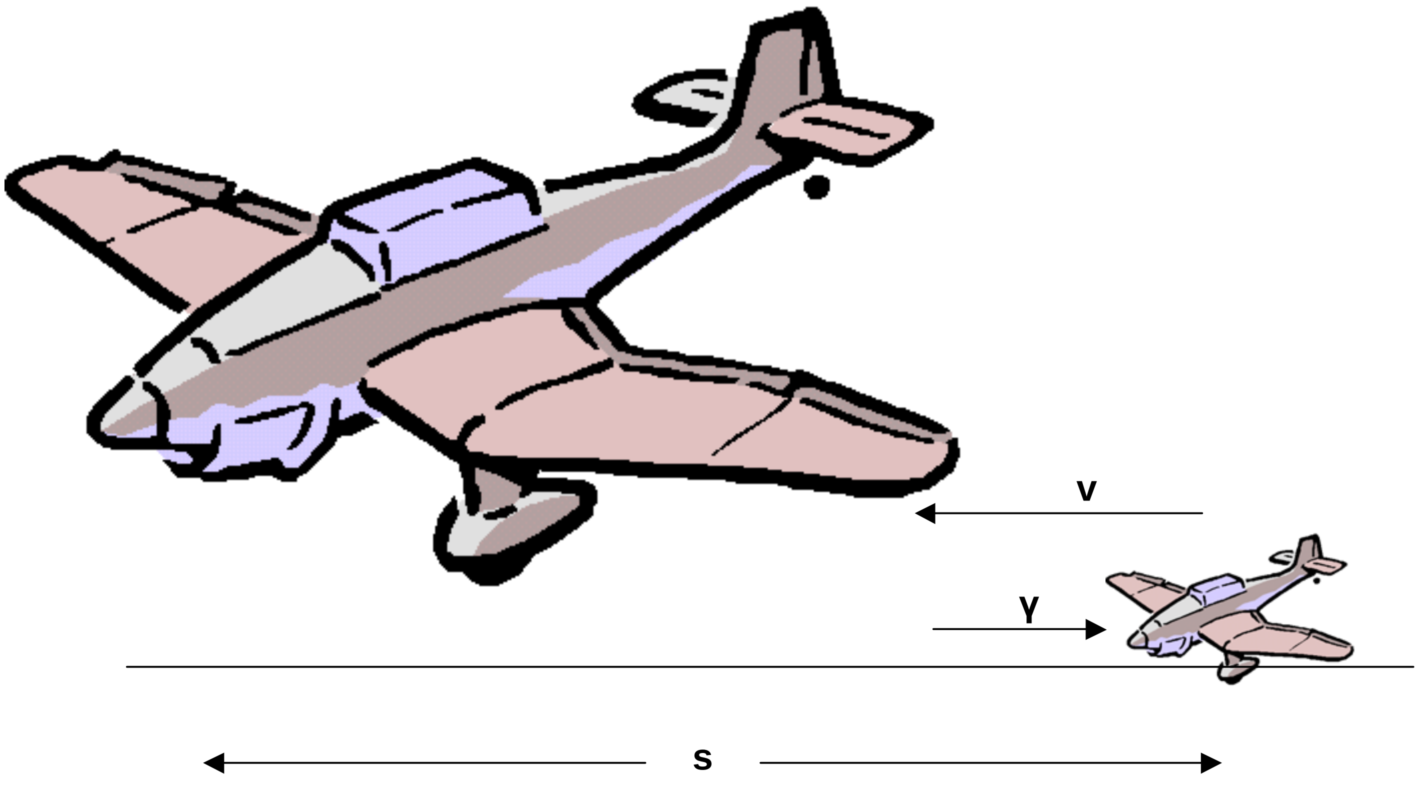
$\theta \sim 1.3$m / s, $\lambda \sim 6000\ 10^{-8}$cm, D ~ 0.5 cm

➔ s ~ 1.3 x 0.5 / ($6000\ 10^{-8}$) m = 10.8 Km

➔ v = s/t ~ 0.5 – 0.6 Km/sec ~ 1800 – 2000 Km/h (!!!)

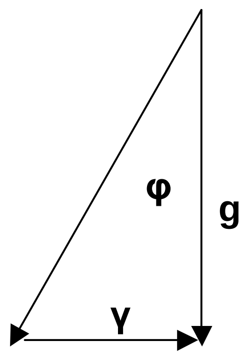


A TV commercial



$g \sim 10\ m/s^2$, $\varphi \sim 30^o$ ➔ $\gamma \sim 5\ m/s^2$, $t \sim 20$ s

$v \sim 100$ m/s = 360 km/h, $s = 0.5\ v\ t \sim$ 2 km



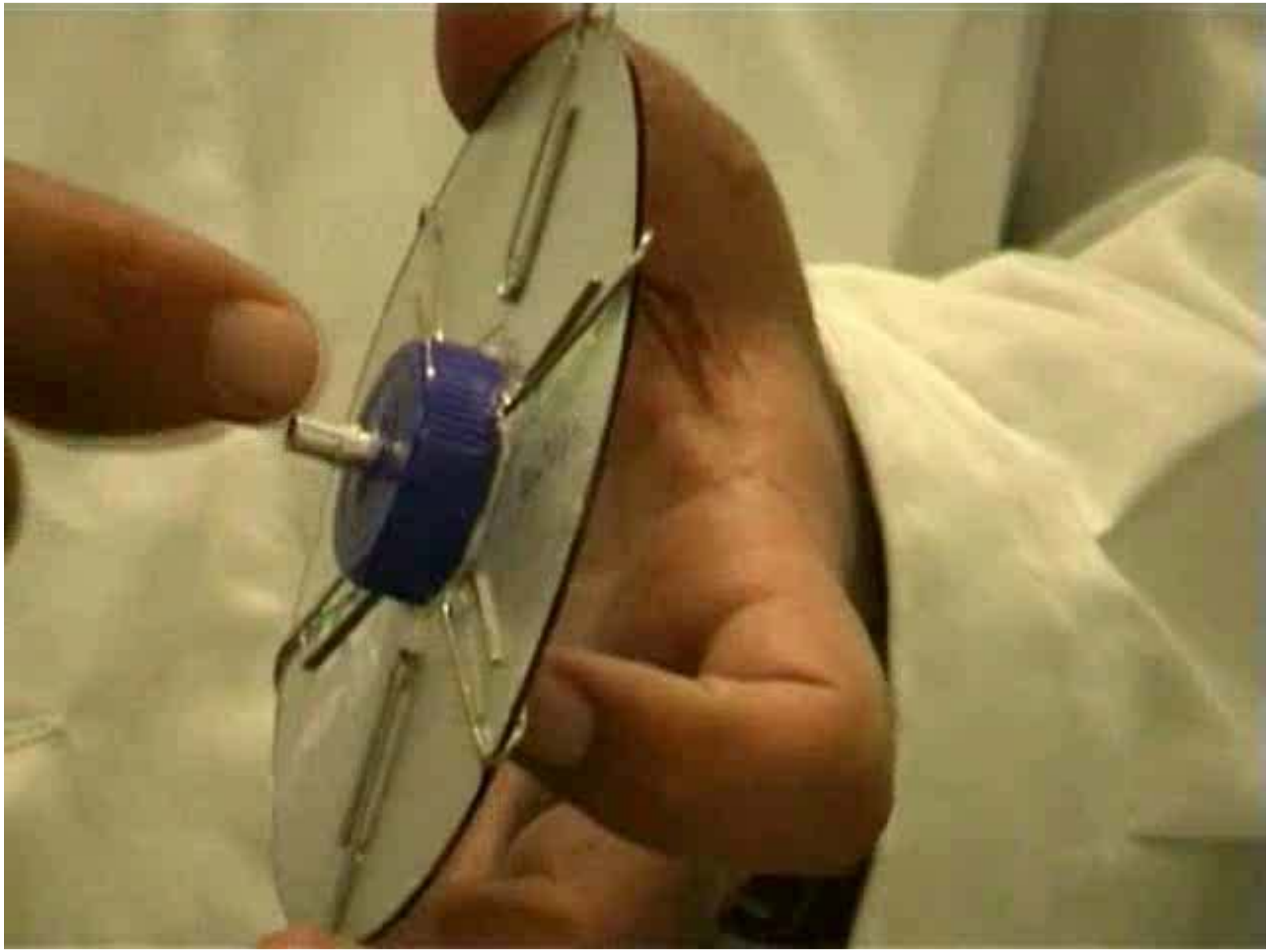
Take off speed (???). Is it similar, smaller or greater? Why?

Variable Lens

More examples

An electric motor

More examples (continued)



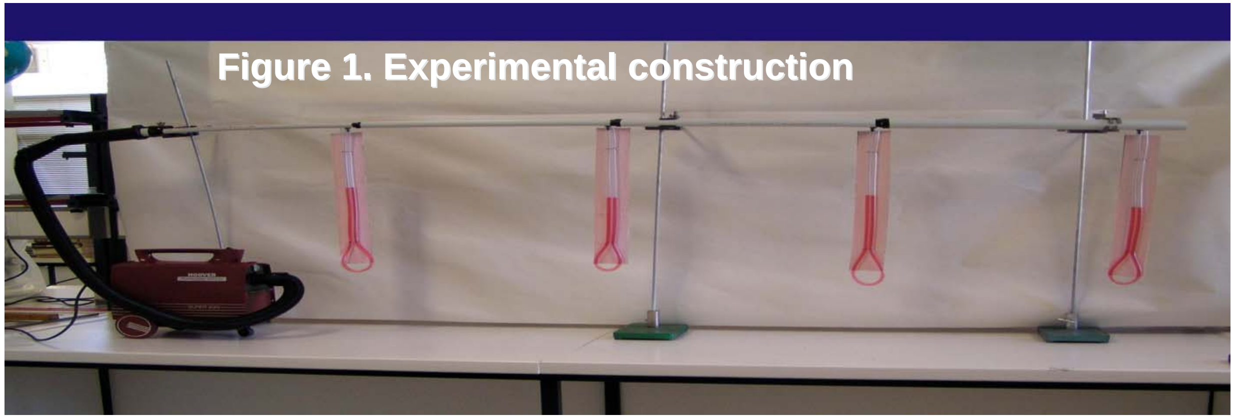
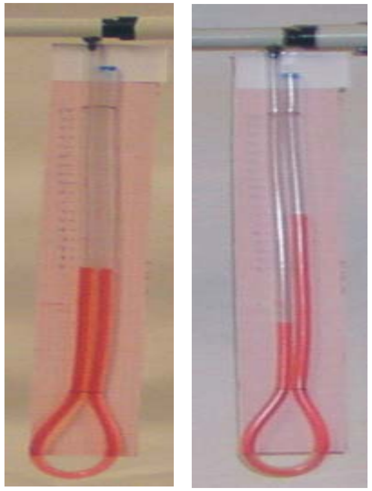


Figure 1. Experimental construction

Figure 2. Pressure Gauges



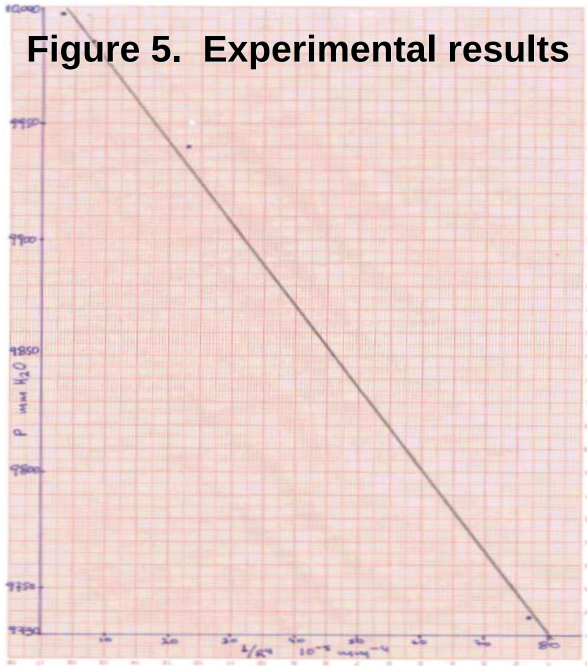


Figure 5. Experimental results

More examples: http://www.clab.edc.uoc.gr/aestit/
http://www.clab.edc.uoc.gr/hsci/

If problems (quite often – students server): ➔ michail@edc.uoc.gr

Epilogue

Realized as assigned projects by students
in the Department for Primary Education of The University of Crete.

Many of them have also been realized partially or totally by school students.

Some indicative responses from the University students are:

I imagined that for Science experiments a special laboratory was necessary

I realized that doing experiments is not so complicated a matter.

I learned to work on my own (a comment made more often by female students).

I realized that what we had learned in school may have direct applications.

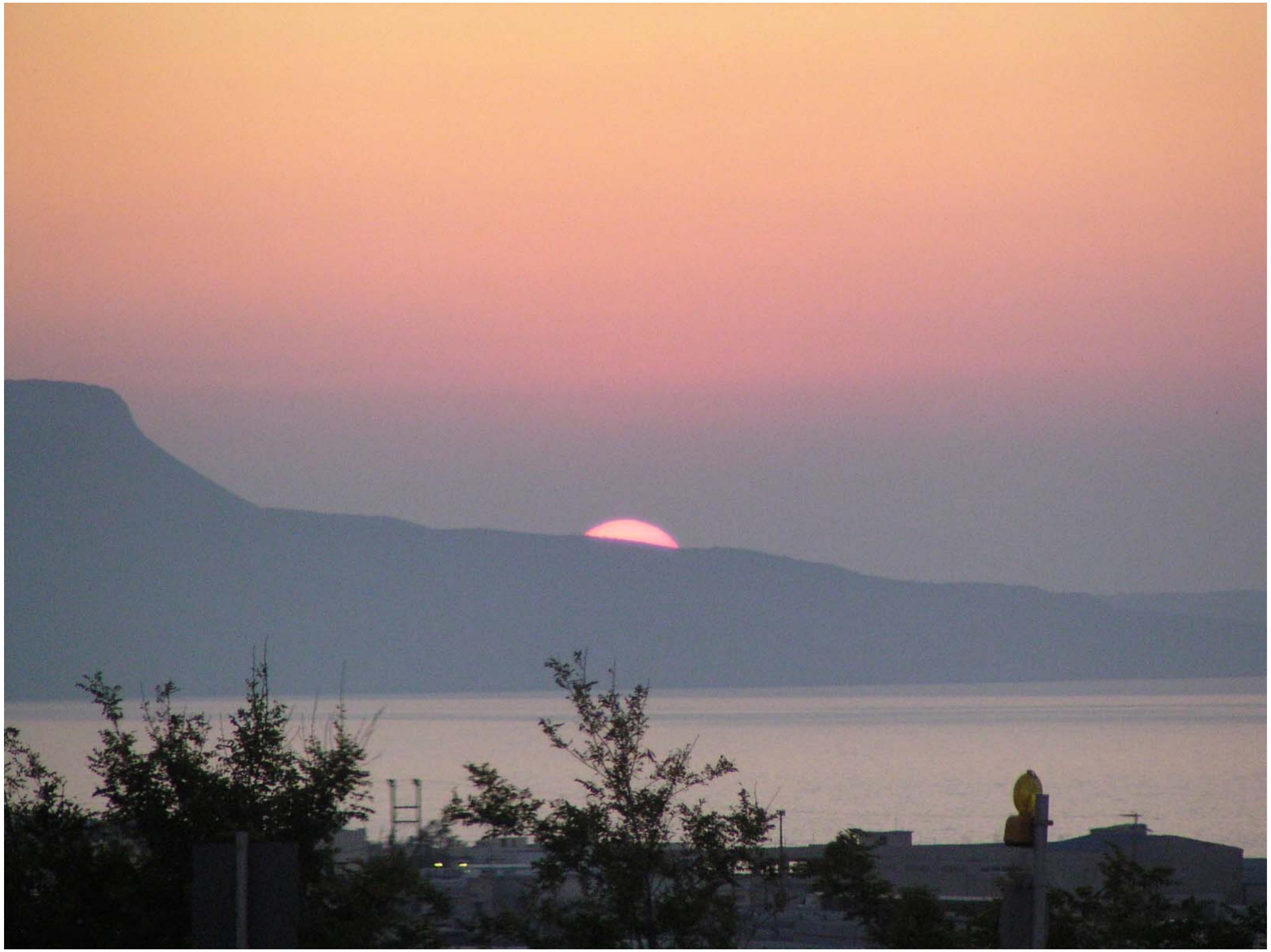
What I learned can be used directly to schools.

The construction helped me to understand what I had only memorized.

I realized a difference between graphs in the Science books and the actual data
referring to the scattering of measurements due to measurement errors,
a fact usually absent in the graphs of textbooks).

It was difficult but I learned to work on my own.

A good course, but the effort I made was worth of two or more other courses.



Thank you