Investigating air resistance using extractor fan filters and plummet in MBL

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Abstract. *A serious motive for this work constituted the following question. Is it possible to find the air resistance dependence on the velocity in the solid movement with the processing of data which results from authentic inquiry-oriented lab activity? For this reason an experimental process was designed and the research was executed by students of the Physics Department. The activity is also proposed for the students of High school that have been taught kinematics and dynamics. For this reason we created educational software which helps the students in the inquiring methodology and the teacher in the educational evaluation of the students. This experimental issue was also given to 400 students of the first grade of High school, in the competition of Physics 2004 and the results of this activity are incorporated in this paper.*

Keywords. Educational assessment, educational software, inquiry-oriented lab, M.B.L.

1. Introduction

Can the students of the Greek High school act as independent researchers examining open type inquiring problems? Can the teacher have the role of an adviser? In what way can inquiring subjects and methodologies be imported in High school? Can we change the way of evaluation of students and move further from the example of educational measurement in the example of educational evaluation? [8], [1], [6]. With which type of problems and activities can we awake the interest of students, develop their critical thought and elevate the character, the processes, the significances and the values of science?

The use of the proposed material does not render the students as scientists and researchers, because the scientist and researcher aims the creation of models, while the students work upon the models we provide them. This role is named "the student as a researcher". There is a need of balance in the preparation of educational process, in order the students to execute the experiments but also not to blunt the peak of discovery. The students that will use the material will act as researchers and scientists in the sense that, formally they do not have the complete knowledge of scientific background on the subject they search.

The role of the teacher differs from the traditional type. The teacher plays the role of adviser which interprets the total picture, he educates the students to use the materials, he records the progress of the students, he offers indications in order the students execute the work that was assigned to them and progressively he withdraws in order the students end their research. Through this process a social act is developed between the students while they collaborate and learn one from the other but also from their schoolteacher. This process is proportional with the one that follows a professor in order to import a postgraduate student in his research. Through his socialization within the members of the inquiring team he learns the inquiring process. This social frame provides a sense of aim and genuineness for the work of the students. Through the process the student confers with the professor who presents the inquiring process either directly (techniques of calculation) or indirectly (proposing the next step). In other words, the professor imports the students into what genuinely means "scientific action". As they advance, they undertake also increased responsibilities concerning the completion of the research, and the determination of the work that

should be done. The professor however continues watching the progress and he provides support by interfering indications in suitable moments. Finally when the students begin to show confidence in his opinion and his advices, his role as an adviser is lost and emerges his new role as a collaborator. This process constitutes a new role for the professor of medium education that will use this proposed material. The use of computers in interconnection with laboratorial provisions via sensors increases the possibilities for independent researches from the students for the following reasons:

a) The teams of students, that have access in computer, create a social environment similar with that of scientists and researchers.

b) A lot of measurements and handlings are executed in very rapidly evolving phenomena.

c) The computer can substitute many individual measuring tools.

d) The computer helps so that the schoolteacher is released from his supporting role. This becomes with suitable educational software that additionally gives the possibility of simulation of meditative processes of the microcosm with MONTE CARLO methods [3].

With regard to the particular subject, the dependence of air resistance from the velocity is not reported to the school books. Is it proportional to the velocity, is it proportional to the square of velocity or something else? Could this appear from the experimental data?

There have been recorded enough misapprehensions, where it is considered that the resistance of air in a big piece of paper that is moving in high speed is proportional to the velocity. In our opinion the best approach was in a school book of PSSC page. 76. As a result of the bibliographic research and the research in the internet, there were recorded enough proposals for activities on the air resistance. The most interesting was that of Professor Paul Hickman of Belmont High School of Boston. The procedure didn't contain a position sensor but only a chronometer and it wasn't executed and lead to no conclusion.

2. The experimentation

With diabetes is engraved a circle of beam R on an extractor fan filters and with scissors is cut the corresponding circular disk. With a balance of precision is measured the mass of this disk. Then seven other disks are cut. A small aperture is opened in the centre of each circular disk and a fishing line is passed through this. A weight is tied up in the end of the line and the other end is fixed in a constant point, in order the line is vertical and stretched. Under the weight a position sensor is placed.

The first circular disk is left to fall from the top of the line roughly 2 m high from the position sensor, activating simultaneously the sensor from the computer. The pairs of rates of place and time are presented in the computer screen.

The diagram of position and time that it was presented simultaneously had the form that appears in figure 1. The process is repeated by adding a disk each time.

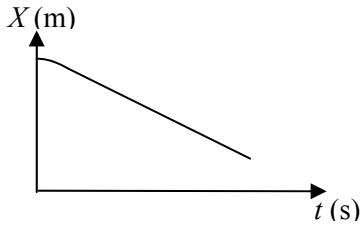

figure 1.

The computer gives the possibility to focus in any department of the diagrams. Three focuses appear in the following figure 2

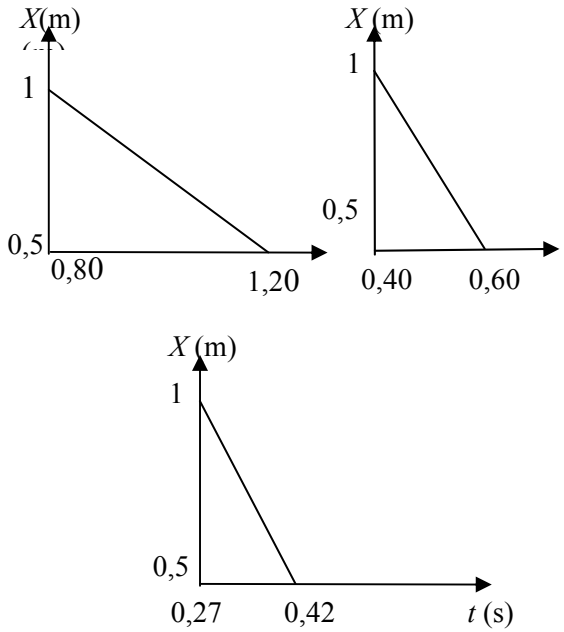

figure 2.

As it appears from the form of the diagram of position and time, the disks very quickly (almost immediately) acquire constant speed.

At terminal velocity the weight of disks equals the air resistance according the first low of motion.

The diagram and the pairs of values as they are presented in the screen by Coachlab 5 are shown in figure 3.

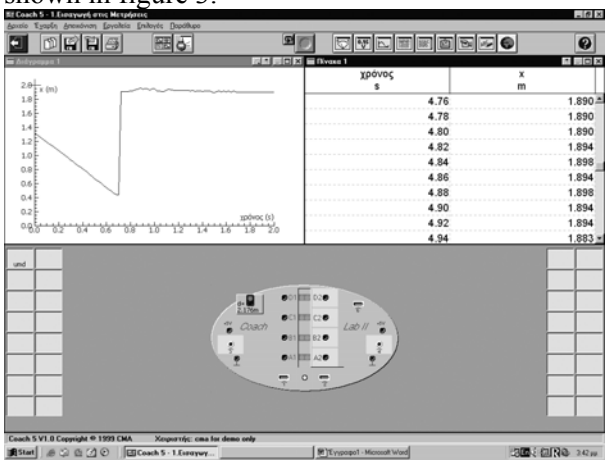

Figure 3.

The air resistance will be finally equal to the weight of disks. In every case, the terminal velocities are calculated by the slope of the three focuses in the diagrams 2,3,4.

Raising the velocity in the square and calculating the quotients of forces with the corresponding speeds as well as with their square, it is realised that the quotients of the resistances with the square of velocity do not differ a lot. Thus it results that the air resistance in this case is proportional to the square of velocity. The number Reynolds helps us to foresee when the air resistance is proportional to the velocity and when it is proportional to the square of velocity and it is fixed as follows:

$$Re = \rho\, v\, d / \mu \quad (1)$$

where: ρ=1,293 kg/m^3, the density of air

v speed of body in in air

d diameter of body

μ = 18,8? 10^{-6} Pa s, the air viscosity

In the following table 1 appears the relation of number Reynolds with the law of resistance.

Table 1.

Reynolds number	Law of resistance
0 – 10	$F = kv$ (no turbulent flow)
10 – 300	Intermediary region
300 - 300000	$F = bv^2$ (turbulent flow)

Concerning the parameters of the experiment, and which should be modified, so that we achieve those conditions in which the air resistance is proportional to the velocity, was used as a criterion the number Reynolds, which oscillates from 0 to 10 for the asked region. Since the density and the ιξωδες air remain stable and the speed will be measured experimental, the only parameter that can be altered is the diameter of the body. Thus a very small body was sought such as a spherule felizol.

The diameter of the spherule is d = 2mm and it was left to fall from h = 1m high. With the digital chronometer the time was measured, t = 1,2 s. The velocity was calculated : $v = h/t$ = 0,83m/s.

First it was found that the reduction of dimensions resulted the decrease of the marginal speed something that contributes positively in the effort of alleviation of number Reynolds.

Knowing that v=0,83 m/s, d = 2mm, r = 1,293 kg/m3, μ = 18,8H 10^{-6} Pa s the Reynolds number is : Re = 115.

The last result shows that we abstain a lot from the region Reynolds (0 to 10) in which the resistance is proportional to the velocity. The result of the reduction in the body dimensions was that the acquired velocity we found is in the intermediary region (10<Re<300) where the relation of air resistance and velocity does not have a certain concrete form.

In order to be in the desirable region 0<Re<10, we will have to use very small objects of diameter (1,8 mms). However then is not possible the recording of the position by the sensor.

The educational software was structured based on the inquiringly evolving educational model [3], that includes the following steps:

1. Trigger of interest
2. Ypothesis expression
3. Experiments
4. Formulation of conclusions and proposals - recording
5. Generalisation - feedback - control

It contains worksheet, report about the educational evaluation of students, a sheet of common self-assessment. It gives the possibility of simulation in a molecular level.

The evaluation could take place with the sheet of report on the laboratorial exercise. This sheet has four sectors. Each sector is evaluated separately.

3. Conclusion

The general conclusion from the above activity is that with the use of filter it is possible the study only of that region where the resistance is proportional to the square of velocity. For the study of region where the resistance is

proportional to the velocity there must be used very small plastic balls of diameter 1,8 mms, a microscope and a digital camera in an experimentation similar to the Millikan experiment.

The roles of the students as researchers and the professor as adviser were observed as it was reported in the introduction and had very encouraging results. It was realised a certain difficulty in the export of conclusions from the experimental data, that however the students overcame alone in a way that was described in the experimentation.

From a first recording of the results of the Physics 2004 competition, it appears a major difficulty in the resolution of problems that does not resemble to the formal problems of school books. Regarding the rest of the problems on the competition, students marked the worst record in this problem. Difficulties were recorded in the comprehension of the meaning of ratio of two sizes. A lot of students do not conceive the meaning of the ratio of two sizes. Many numerical errors were recorded in the calculation of the bent and errors about the comprehension of meanings. Also a major weakness was detected in the export of information from experimental data.

A lot of students of 14 to 17 years old, express the wish to deal with impressive and inquiring problems of an open type, while their interest for the formal problems of school handbooks appears to decrease. They ask from their professors more provocative and interesting problems that could take place in the laboratory, be accompanied by measurements and supported by suitable software. The professors do not have educational material with definite educational methodology, they do not exploit the interest of their students and they give extra problems which discourage their students.

We consider that with the proposed material we will help students to overcome this lack of interest in order to start acting as independent researchers and the professor to take the role of the adviser. Also it is suitable for the educational evaluation that takes place in the laboratory by the professor with the help of suitable tools of evaluation. It creates a new social environment using new technologies and helps in the appointment of the character, the processes, the significances and the values of Science.

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