

# Utilization of New Technologies in Science Teaching to Improve Student Learning at Engineering Introductory Physics Courses

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**Abstract - This project aims to enhance student-learning acting in two fronts. The first one is the intensive use of laboratory experiments as a complement to regular classes. The second step is how to assist these experiments integrating them with computer data acquisition. The innovation is that students are able to perform a computer simulation before the experiment. With software developed to integrate simulation and experiment, the student could predict the behavior of a physical situation, perform the experiment and compare both results to make a synthesis of them.**

At this stage of the project, we developed two experiments. The first one is a pendulum, which permit students observe the behavior of dumped oscillations. The second experiment consists in an air track with a data acquisition system and an impact transducer, based on a LVDT (Linear Variable Differential Transducer), which performs evaluations in motion, energy and collisions, in order to verify the conservation of linear momentum.

Both, data acquisition hardware and interactive software, were developed in Computer Engineering Laboratories at UnicenP, with continuous interaction of the students, creating experiments and interfaces that points directly to students most frequent questions. Beside that, we could reach another objective: how Physics, Computer Science and Electronics interact themselves to generate knowledge. This point achieves the search for a multidisciplinary effort on Engineering teaching.

*Index Terms* – Multidisciplinary teaching, Computer assisted experiments, Oscillations, Kinematics.

## INTRODUCTION

It is a well known fact that freshman students technologies programs have difficulties in how to describe a physical situation or trying to identify which are the relevant parameters to take into account or how to describe mathematically the system behavior, in order to be able to analyze the outcomings of an experiment and predict something about the system. One way to face this problem is by using computer simulations, which have been established as an efficient way to make learners improve their physical modelling about a system. This could be achieved once that computer simulations provide learners with the opportunities to test the understanding about a physical phenomenon by proposing and testing alternative hypotheses [1]. In this way,

they can also test and learn about the causalities relations among the parameters of the given situation [2].

However, computer simulations can abstraction totally students from the real world, in a sense that lot of subtle aspects as friction, air resistance and viscosity, are neglected or not modelled in a convenient way. This is why some researchers [3] claim that computer simulations should not replace the first laboratory contact, in order to avoid this lack of contact with the reality. As a pre-established model, ignoring new facts that could emerge from experiments, computer simulations could affect the students' development about scientific discovery.

This project intends to integrate computer simulations with real Physics laboratories experiments, but in an interactive way, where the student can perform a computer simulation before its interaction with the real experiment, to predict the system's behavior. With manipulating the experiment, the student is going to see, on a computer screen, the real time measurements of the relevant variables of the proposed situation. Besides this interactivity, the computer will not be a substitute to the calculations and measurements, once this certainly could be a wrong strategy, as this procedure avoids learning about how to precede data manipulation on a laboratory. However, the computer-assisted experiment will be a bridge between the real physical situation founded on an experiment and the textbooks Physical approaches.

The procedure is described below:

- The student receives the description of a physical situation and it is asked to predict the behavior of some parameters.
- The student performs a computer simulation to confront with his prediction.
- After that, he/she performs a real experiment in a Physics Laboratory. This experiment is computer – assisted and the student is able to observe the real time evolution of physical quantities.
- The student analyses both results and elaborate conclusions about the results of the experiment.
- The conclusions are discussed with an instructor.

## COMPUTER SIMULATION AND COMPUTER-ASSISTED EXPERIMENTS

Since the main students` difficulty has been identified, the Physics computer simulation software MODELLUS [4] becomes more frequently used at both, classroom and home activities, as proposed in [5]. But, some questions should be

taken into account. First of all, computer simulation represents only a piece of the physical reality, as programmed by the simulation. As a first contact, this has its convenience. But, further questions as “Has the friction a relevant role in this simulation?” are put outside of the computer simulation. However, the use of real laboratory experiments is indispensable in order to make students reflect about the real physical world. From this point of view, the utilization of computer-assisted experiments at Physics laboratory classes has been irreversible. A complete review about this topic was described in [6]. As proposed there, we should emphasize the following:

- By helping the experiment data acquisition, computer increases the number of available data, allowing a general vision of the physical phenomena.
- As a result, student has more time to concentrate at the development of the relevant physical aspects.
- More experiments could be explored, once computer is able to handle with a larger number of data.
- The measurement process allows students interact with technologies such optical sensors, electromagnetic transducers and device calibration.

The process above does not suggest that manual data analysis must be skipped by students. Beside this, one must be careful to do not permit that computer makes all the data acquisition. The direct contact with both, data analysis and data acquisition, gives an idea to students of the real difficulties at the data mining process.

#### DEVELOPED COMPUTER-ASSISTED EXPERIMENTS

In this topic will be explaining the construction of three measurement applications for physics laboratories: one impact transducer, one complex pendulum and an air track. These equipments are developed to assist practical physics experiments and to become easier to understand these physics phenomena.

#### AIR TRACK LINEAR DISPLACEMENT, VELOCITY AND ACCELERATION

Linear Displacement phenomena experiments are performed using an air track. The objective is measure displacement of an object without attrition loses. Nowadays, the experiments carried through at physics laboratories have photo-interrupters sensors. This type of sensors does not allows continuous measurement, they work only starting and stopping a chronometer. These sensors are assembled with a previous known space between them, with that is possible to obtain the object velocity through simple formulas. However, these velocities are only average speed between the start and stop photo-interrupters, and do not show the results we want to know. Despite of these sensors allow a great number of experiments they have a major problem that only can measure average speeds. We propose an acquisition system that measure the car’s position in real time. This system must be assembled without devices on the car that could cause an overweight that produces errors in the measures.

For this reason, the displacement was measured through an optical system based on photo-emitters and photo-receptors placed on the air track extremities. The principle of actuation is that the light emitted by the photo-emitter is reflected on the car over air track and returns to photo-receptor. The point where the light returns to photo-emitter is proportional to distance of reflection, this principle is shown in Figure 1, the distance of the first object is less than the second object and the points of distance reflection are different for the two situations.

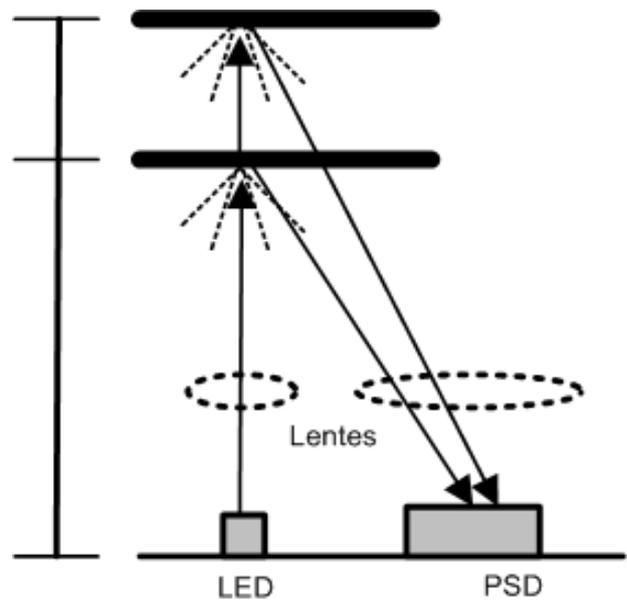


FIGURE 1  
THE RECEPTION POINT COMPLY WITH OBJECT DISTANCE

This system is known as PSD (Position System Device) and is very used in industrial applications. It was connected one sensor on each extremity of air track to obtain position from each car, Figure 2.

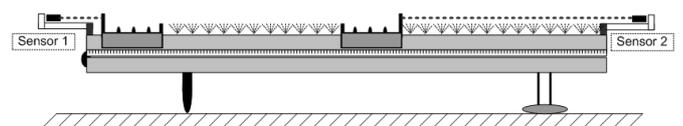


FIGURE 2  
EACH EXTREMITY HAS A SENSOR TO MONITOR THE CAR DISPLACEMENT

The PSD sensor has an exponential response. There are two ways to obtain the displacement through sensor response. First is use a table that has displacements values for sensor response values, this method is very poor and it can generate serious errors. The best method is use a logarithm amplifier to obtain a linear response.

The last step is convert an analog value to digital, analyze this value and send it to computer, these tasks is made by a microcontroller. This microcontroller has the function of reduce data send to computer, and while cars are in repose state, the computer does not receive any data. The block diagram of electronic circuit is shown in Figure 3.

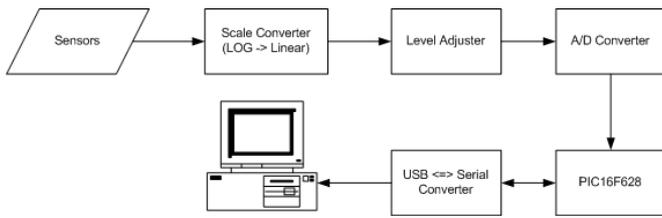


FIGURE 3  
BLOCK DIAGRAM OF ELECTRONIC CIRCUIT

Microcontroller communicates with software to simulate the air track functioning. This air track software obtained information about position of cars and can make a series of calculus to obtain other information, like velocity (instantaneous and average), acceleration (instantaneous and average). Averages can be defined over two position points or time interval. Also, the curves of these information are presented by a graphical way. Air track image with real time actualization show the displacement of cars. The air track software is showed in Figure 4.

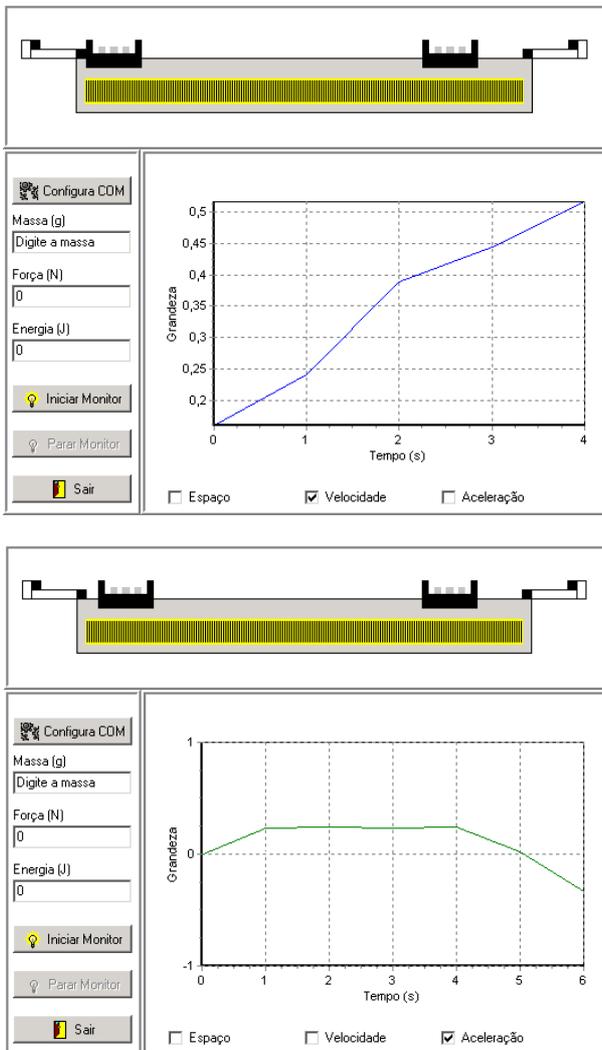


FIGURE 4  
AIR TRACK SOFTWARE, SHOWING VELOCITY AND ACCELERATION

The device calibration should compare the car acceleration (a) and gravity acceleration (g) through relation (1)

$$a = g \cdot \sin \theta \quad (1)$$

where,  $\theta$  is the angle that gives the air track inclination. At the city of Curitiba-Brazil, g takes the value of  $9.79 \text{ ms}^{-2}$  and the results are shown in Table I.

TABLE I  
CAR'S ACCELERATION AT AIR TRACK

$\theta$ (degrees)	Car Acceleration ( $\text{ms}^{-2}$ )	
	obtained	expected
5	0.838	0.855
10	1.720	1.703
15	2.555	2.539

### LINEAR IMPACT TRANSDUCER

In a collision between two objects, these ones applied forces of great intensity one over other at a short time interval. These forces are internal to the system and are significantly bigger than any external force during the collision. The total linear moment before and after the collision remains constant, however, the total kinetic energy of the system remains constant only in an elastic collision. During the experience, the speeds of two objects (cars), moving itself over an air track without attrition, are measured before and after a collision frontal for the elastic and inelastic collisions. Currently, the experiments are executed over the air track, where are positioned two cars. The first one starts the experiment with an initial velocity ( $V1i$ ), known through a pair of photo-interrupters. After a few time, the first cars shocks with the second one, initially in repose. The final speed ( $V2f$ ) is obtained using other two photo-interrupters, these ones located at the end of the air track. This experiment is detailed in Figure 5. With the physical relation between moment and energy, we can obtain the power of the collision between two cars, therefore, this is an indirect method of measuring these value.

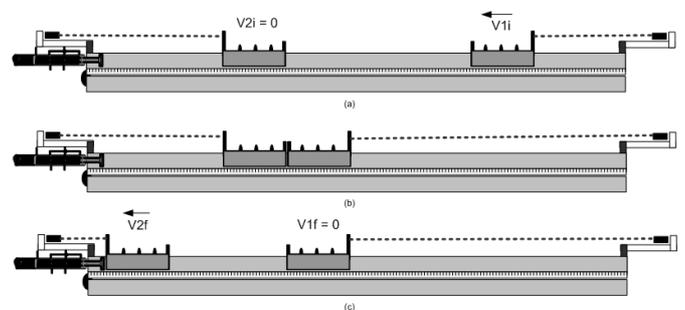


FIGURE 5  
COLLISION EXPERIMENT

To provide a direct form to measure the force applied by first car over the second car, it is necessary to use a sensor that

receives the impact from the car at the end of air track. With this form will not have a significant loss in the mobility of cars in the diverse experiments that are developed over the air track.

The impact sensor must be robust since it receives impacts right-handers from objects. Being necessary its correct setting too. The precision and band of measure are also essential factors in the experiments. Based on this information, was defined that the best type of sensor would be the LVDT (Linear Variable Differential Transformer). The LVDT is an important and common sensor for displacement in the industrial environment. A LVDT consists of three coils of wire wound on a hollow form. A core can slide freely through the center. The inner coil is excited and while core moves a current is inducted on secondary coils. It is shown in Figure 6. LVDTs have a great linear range from  $\pm 25$  cm down to  $\pm 1$ mm, and a rapid time response.

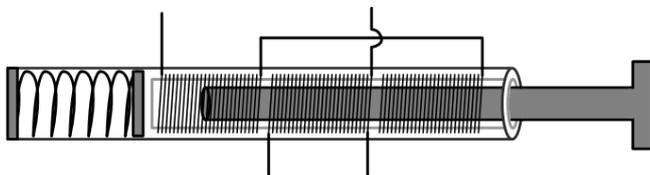


FIGURE 6  
LVDT INTERNAL STRUCTURE

In order to observe the LVDT linear response, we perform a calibration with a wide range of applied forces on device. The results are shown in Figure 7, that confirm the expected device behavior.

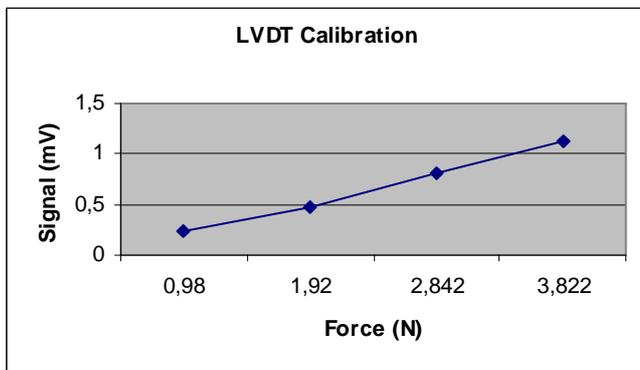


FIGURE 7  
LINEAR LVDT RESPONSE

### DUMPED PENDULUM OSCILLATIONS

The practical studies of oscillated displacement have simpler example the standard pendulum. However, this type of movement has a great number of variables and, normally, it is of difficult understanding for students. Aiming to improve the experiments carried through in the practical physics classes we were developed a data acquisition system for this experiment and a software that execute a simulated experiment showing the main principles, like frequency constant, damping curve.

The practical classes of oscillatory motion has a great number of manual actions that made constants errors and difficult to understand for students. Nowadays, a student drops the pendulum with known amplitude in the same moment that other student start a chronometer, it is stop when pendulum complete one period.

The physical pendulum developed has part where the optical sensor and the axis are connected, Figure 8.



FIGURE 8  
CONNECTION BETWEEN OPTICAL SENSOR AND MECHANICAL AXIS

This part was developed with the same principle of computer mouse, using a disc allow and block the light beam with an angular space of two degrees. The light beam is provided by two photo-emitters, it is point to two photo-receptors spaced forty five degrees, this displacement make a delay in signal that is used to know the direction of motion.

In Figure 9 is shown the mechanical part of pendulum that coupling the sensor. Also in the same figure in upper part, it is shown the led position relative to the disc. When the led's light beam cross over disc, the system recognizes a pulse. For the under led, the disc blocks light beam, and the system stay with zero value. The waveforms obtained by successive pulses are also shown in Figure 9.

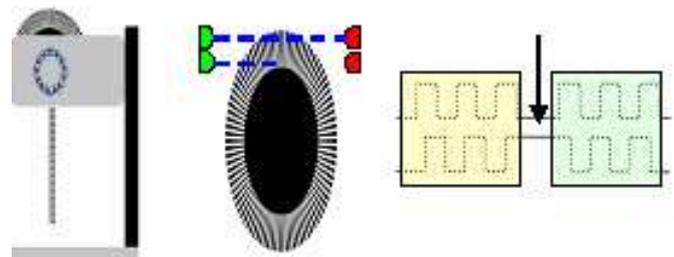


FIGURE 9  
SIGNAL ACQUISITION

A microcontroller decodes the sensors output, detecting the position of the pendulum. The pendulum software receives a value that represents the pendulum position referent to the repose position and calculates motion data, like, amplitude, frequency and period. Also, the information about energy, potential, kinetic and damping are shown in graphs to a better understanding. The pendulum software is showed in Figure 10.

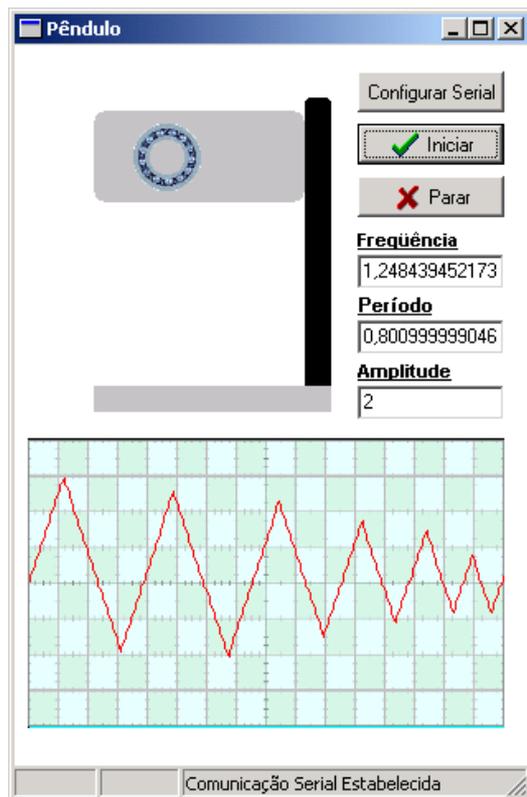


FIGURE 10  
PENDULUM SOFTWARE

### COMPARISON BETWEEN SIMULATED AND EXPERIMENTAL DATA

As commented above, one of the targets of this project by using computer assisted experiments beside computational simulation is allows students make a comparison between the “ideal” reality simulated by computers and the real situation found in laboratories. A general summary is shown below:

- *Air Track: Displacement, Speed and Acceleration*

As can be calculated by using Table I, the mean deviation to the motion quantities (displacement, speed, acceleration) is situated around 2%. The simulated results given by MODELLUS software are considered as the standard ones. This difference could be explained by some effects when the car slides along the air track: little collisions between the car and track side waste mechanical energy and so on.

- *Dumped Pendulum Oscillations*

In this experiment, the mean deviation from simulated results are around 5% to the angular displacement and 8% to the amplitude. In this case, such deviations are due to the system projected to make the mesurement. As the disc has black and white strips with an angular width of two degrees, this can affect the measurements precision. Also, the pendulum’s motion equation is not linear and depends on the sinus of the angular displacement.

### CONCLUSIONS

#### Software Results

- Clear and user-friendly interface.
- The student may observe a real time evolution of the physical quantities.
- The real-time graphics plotting avoid some misconceptions like do not distinguish between position graphic and the real car trajectory.
- It is possible make experiments to observe the mechanical energy conservation.

#### Hardware Results

- The hardware was built with standard and cheap components, which makes it is very useful at many institutions.
- At the air track experiment, the PSD sensors are assembled on the air track and do not on the car. This is very important in order to make a data acquisition system that does not alter the original experiment feature.
- The hardware can be easily adapted to other experiments, like collisions, linear momentum, over dumped oscillations and so on.

The main results of the utilization of computer-assisted experiments at laboratory Physics classes of UnicenP point to a significant increase in the student learning and understanding [7], [8]. The experiments make more easy and useful to explore both, the subtle and remarkable features of a given physical situation.

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