Improving Teaching and Learning by Using Computational and Electronic Instrumentation Resources on Engineering Introductory Physics Courses

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Abstract *—By 20 years ago, while Computation Science started it process of popularization, the general opinion was that, in a few years, we would have a massive application of computers in the classroom. This is a natural re action every time when a technological evolution has real possibilities of application in Science Education. Today, this is a point of view of difficult convergence. Among lots of opinions, we have people that say computers can support a huge effort on tea ching Science. An opposite opinion have ones that says computers do not permit students a complete contact with nature, affecting in a negative way how students can learn to measure and calculate. Now days we know that the path to be followed sets computer s as an accessory on science learning, once they have a great potential do improve student achievement. So, the computer is a tool that is able to mediate knowledge transmission, but it is not the final stage of teaching and learning.*
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 innovat ion here is that student 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 bot h results in order to build a synthesis of them.
In the first stage of the project, we are concerned in three experiments. The first one is a pendulum, which permit students observe the behavior of dumped oscillations. The second experiment consists in a a ir track with a data acquisition system. This system is able to measure time and displacement in a real time way. Integrated with software it can show the evolution of physical quantities. Finally, the third experiment is a impact transducer which perform evaluations in collisions, in order to verify the conservation of linear momentum.
The first results of the project, assisting classes with these experiments integrated with computer simulation, have shown a significant enhancement in the student -learning process.

Index Terms *— Physics Laboratories, Computer Assisted Experiments, Real Time Data Treatment.*

INTRODUCTION

It's a well known fact that first years students of technologies courses have difficulties on 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 behaviour, in order to be able to analyse 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 abstract totally students from the real world, in a sense that lots 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.

By the other hand, other studies [4] suggest that effects of simulation-based learning are more effective when the simulation is embedded in an environment that could support some aspects of discovery learning.

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 behaviour. Manipulating the experiment, the student is going to see, on a computer monitor, the real time measurements of the relevant variables of the proposed situation. Besides this interactivity, the computer won't 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. So, 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 is asked to predict the behaviour of some parameters.
- The student performs a computer simulation to confront with his prediction.
- After that, he performs a real experiment in a Physics Laboratory. This experiment is computer –assisted, so 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.

NEW TECHNOLOGIES ON PHYSICS EDUCATION

By 20 years ago, while Computation Science started it process of popularisation, the general opinion was that, in a few years, we would have a massive application of computers in the classroom [5]. This is a natural reaction every time when a technological evolution has real possibilities of application in Science Education. Today, this is a point of view of difficult convergence [6]. Among lots of opinions, we have people that say computers can support a huge effort on teaching Science. An opposite opinion have ones that says computers do not permit students a complete contact with nature, affecting in a negative way how students can learn to measure and calculate. Now days we know that the path to be followed sets computers as an accessory on science learning, once they have a great potential do improve student achievement. So, the computer is a tool that is able to mediate knowledge transmission, but it is not the final stage of teaching and learning. Thus, new technologies, like utilization of computers on Physics education, could in fact improve students learning about the subject, once it take part on a major project coherent with this proposals [7].

THE EXPERIMENTS

Physical Pendulum and Dumped Oscillations.

The study of oscillations is of a big relevance on Mechanics [8]. Most of the Nature phenomena involves this subject, as engineering applications [9], Biology [10], even on human resources administration [11]. On chaotic phenomena, oscillations play a central role [12].

Besides this, one can observe that most of students have great difficulties on handle with this subject [13]. We can refer such difficulties like how to describe in a qualitative and quantitative way the evolution of physical parameters. This carries students to lots of misconceptions about the phenomenon. So, the development of a computer-assisted experiment to help students on how to handle with this is very justifiable. The experiments made until today are very crude on a sense that perform measurements like period (and frequency) are almost impossible to be carried out with good precision. This project attacks this point using instrumentation techniques.

Air Track and Linear Displacement.

Almost Physics courses everywhere starts with the study of motion. The aim of that is this kind of subject could be an efficient way to show students how can be described in a mathematical language a physical phenomenon. Most of the experimental sets at disposal to sale lacks some part of this, specially when is necessary to perform de evolution of average to instant quantities, such velocity and acceleration. On this project, the air track was developed in order to be able to show students, in a real time procedure, how this is done.

Impact Transducer.

This subject carries with it lots of students' misconceptions about Conservation of Linear Momentum and Conservation of Energy, which involves the concepts of elastic and inelastic collisions. One way to handle with this is constructing an impact transducer, which is working together with the air track. The transducer could help students on observations about the Impulse and Linear Momentum Theorem, which establishes the Conservation of Linear Momentum. With this in mind, the learner could dedicated more attention to check if the energy is conserved or not.

MATERIAL AND METHODS

In this topic will being explain the construction of three measurement applications for physics laboratories: one impact transducer, one complex pendulum and a air track. These equipments are developed to assist practical physics experiments and to became more easy to understand these physics phenomena.

LINEAR DISPLACEMENT

Linear Displacement phenomena experiments are carried through a air track, shown in figure 1. The objective is measure displacement of a object without attrition loses.

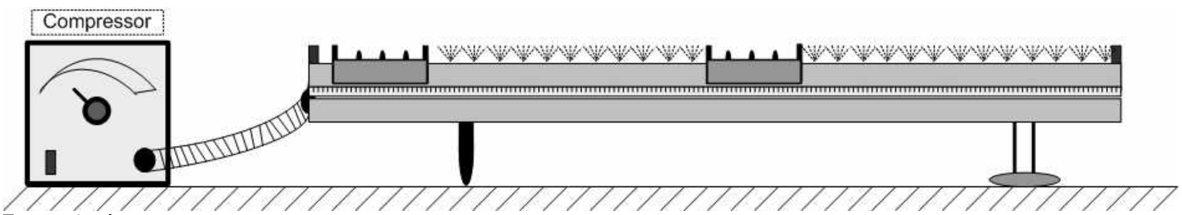

FIGURE 1 – AIR TRACK USED FOR PHYSICS EXPERIMENTS

Current Experiments

Nowadays the experiments carried through at physics laboratories have photointerrupters sensors, shown in figure 2. This type of sensors don´t allows continuous measurement, they work only starting and stopping a chronometer. These sensors are placed 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 photointerrupters, and don't show the results we want to know.

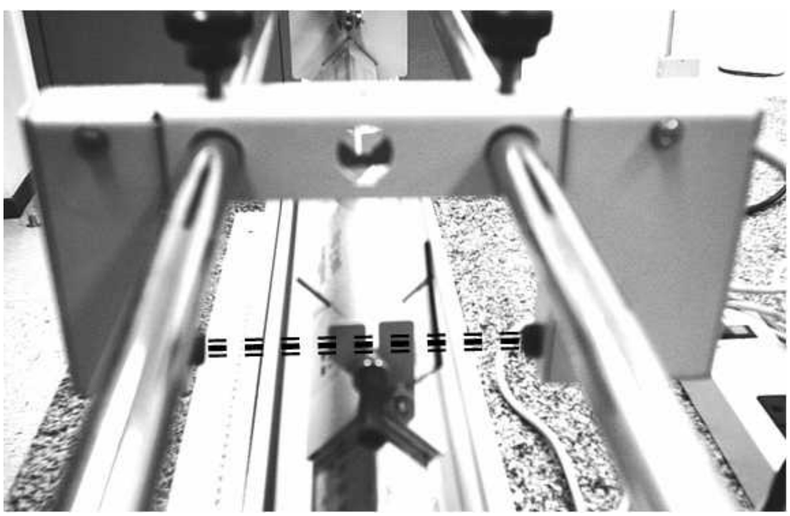

FIGURE 2 – ORIGINAL PHOTOINTERRUPTERS

Considered Equipment

Despite of these sensors allow a great number of experiments they have a major problem that only can measure average speeds.
We propose a acquisition system that measure the car's position in real time. This system must be mounted without devices on the car that could cause an overweight that produces errors in the measures.
For this reason, the displacement was measured through a optical system based on photoemitters and photoreceptors placed on the air track extremities. The principle of actuation is that the light emitted by the photoemitter is reflected on the car over air track and returns to photoreceptor. The point where the light returns to photoemitter is proportional to distance of reflection, this principle is shown in figure 3, the distance of the first object is less than the second object and the points of distance reflection are different for the two situations.

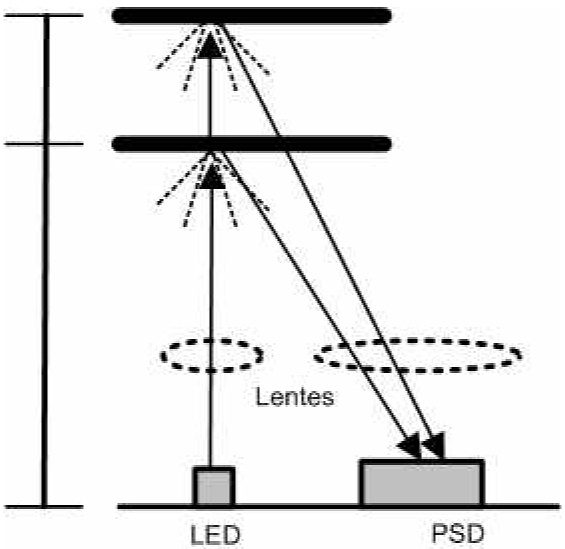

FIGURE 3 – THE RECEPTION POINT COMPLY WITH OBJECT DISTANCE

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 4.

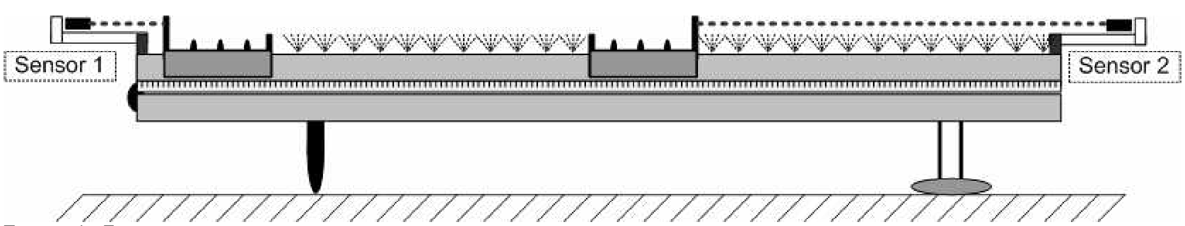

FIGURE 4 – EACH EXTREMITY HAS A SENSOR TO MONITOR THE CAR DISPLACEMENT

The PSD sensor has a exponential response. There are two ways to obtain the displacement though sensor response. First is use a table that has displacements values for sensor response values, this method is very poor and can cause serious errors. The best method is use a logarithm amplifier to obtain a linear response.
The last step is convert a analog value to digital, analyze this value and send it to computer, these works is made by a microcontroller. This microcontroller has the function of diminish data send to computer, and while cars are in rest state, computer don't receive any data. The block diagram of electronic circuit is shown in figure 5.

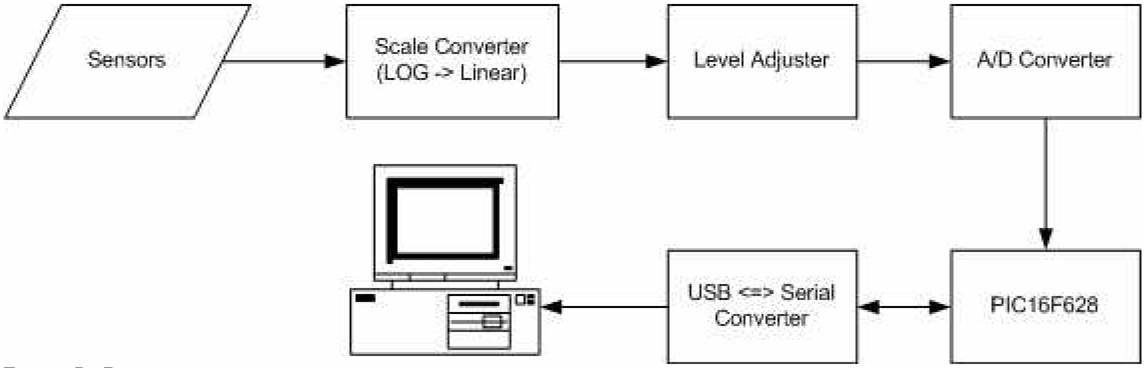

FIGURE 5 – BLOCK DIAGRAM

Microcontroller comunicates with software develop to simulate the air track functioning. These software obtain 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 theses information are presented by a graphical way. A air track image with real time actualization show the displacement of cars. In figure 6 are shown the software main screen.

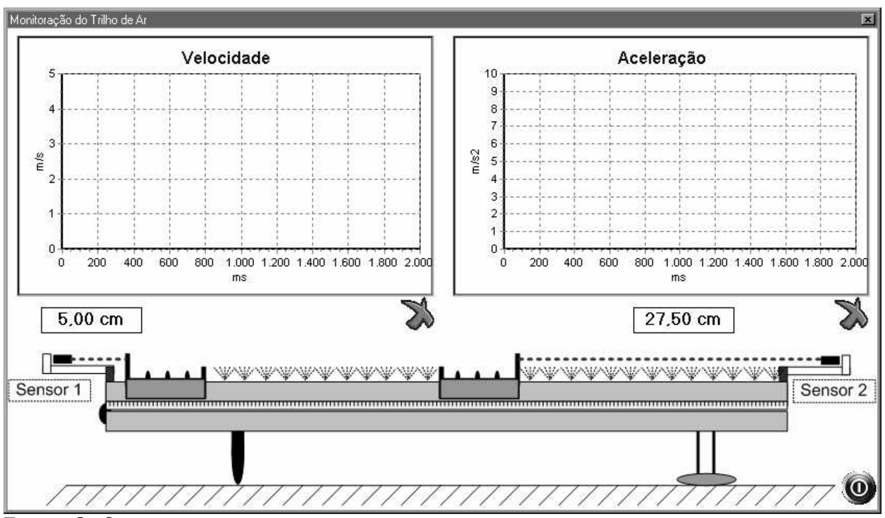

FIGURE 6 – SOFTWARE MAIN SCREEN

PENDULUM

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 develop a data acquisition system for this experiment and a software that realize a simulated experiment showing the main principles, like: frequency constant, damping curve.

Current Experiments

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 a known amplitude in the same moment that other student start a chronometer, it's stop when pendulum complete one period.

Considered Equipment

The physics pendulum developed has a special part where the axis is connected, figure 7.

FIGURE 7 – SPECIAL PART OF PENDULUM

This part was developed with the same principle of computer mouse, where a disc allow and block the light beam with an angular space of two degrees. The light beam is provided by two photoemitters, it’s point to two photoreceptors spaced forty five degrees, this displacement make a delay in signal that is used to know the direction of motion.
In figure 8a is shown the mechanical part of pendulum that coupling the sensor. Also in figure 8b, is shown the led position relative to the disc. When the led’s light beam crosses disc, the system recognizes a pulse. Shown in the figure upper part. For the under led, the disc blocks light beam, and the system stay with zero value. The waveforms obtained by successive pulses are shown in figure 8c.

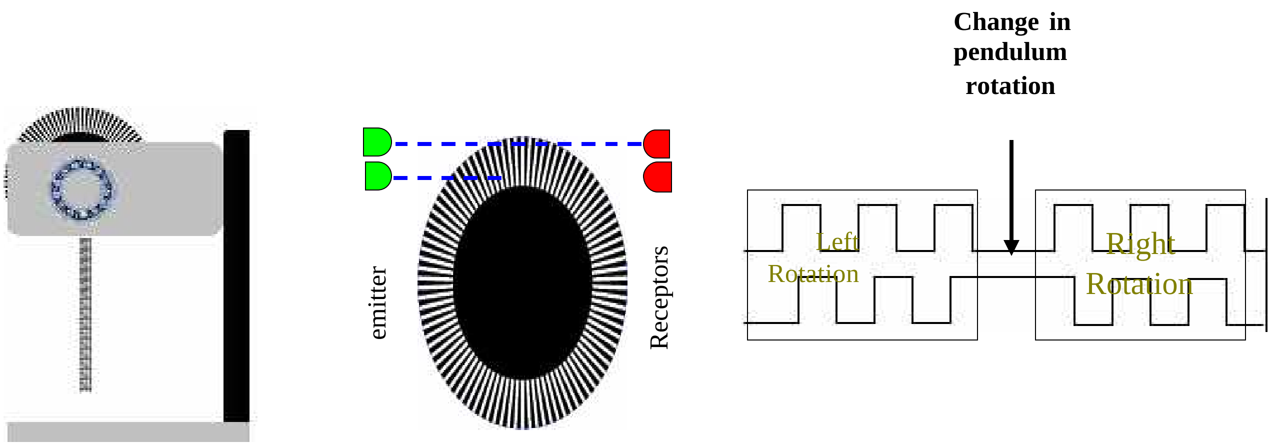

FIGURE 8 – A) POSITION OF DISC IN THE MECHANICAL PART; B) EXAMPLE OF PASS/BLOCK LIGHT BEAM; C) WAVEFORM RESULT

A microcontroller decodes the sensors output, detecting the position of the pendulum, as described at flowchart shown in figure 9.

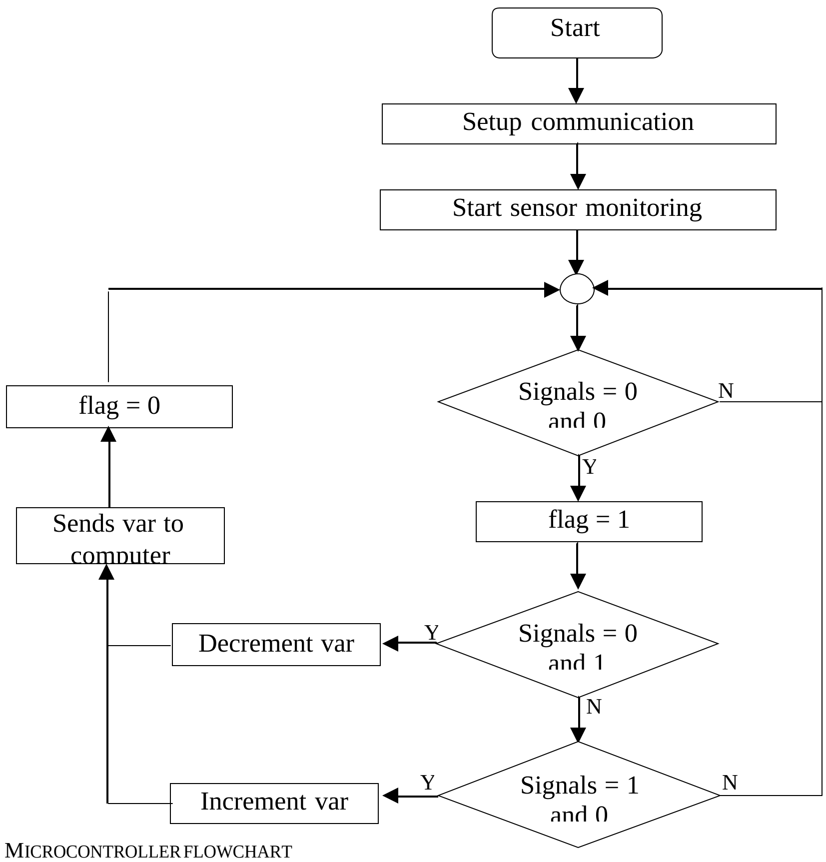

FIGURE 9 – MICROCONTROLLER FLOWCHART

The software receives a value that represents the pendulum position referent to the rest position and calculates movement data like: amplitude, frequency and period. Also, these information about energy, potential and kinetic, and damping are shown in graphs to a better understanding. In figure 10 we presents the program main interface.

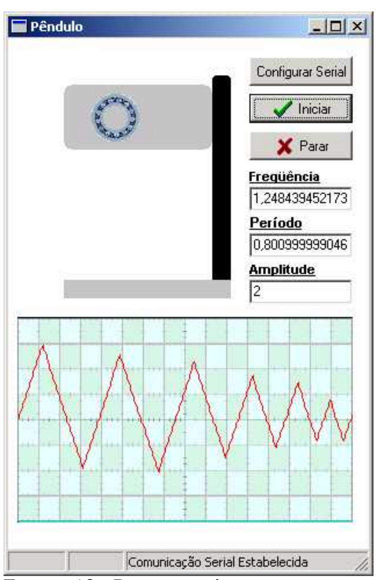

FIGURE 10 – PENDULUM'S PROGRAM MAIN INTERFACE

IMPACT TRANSDUCER

In a collision between two objects, these ones exert 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.

Current Experiments

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 rest. The final speed vf2 is obtained through other two photo-interrupters, these ones located at the end of the air track. This experiment is detailed in figure 11.
With the physic relation between moment and energy, we can obtain the power of the shock between two cars, therefore, this is and indirect method of measuring these value.

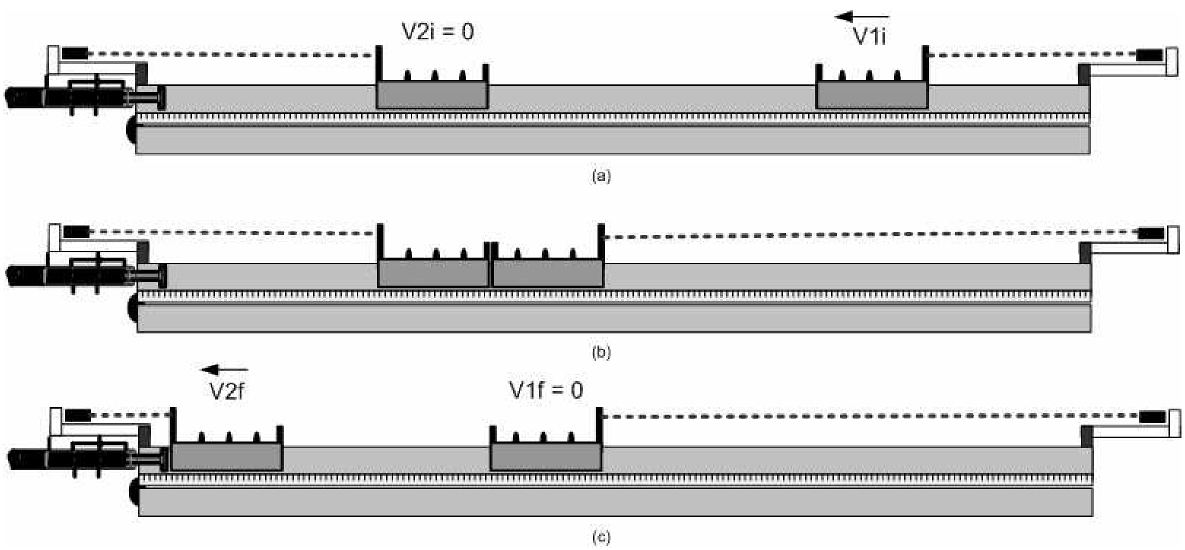

FIGURA 11 – MAIN EXPERIMENT OF LINER MOMENT

Considered equipment

To provide a direct form to measure the force exerted 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 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. An 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 secondaries coils. It´s shown in figure 12. LVDTs have a great linear range from ± 25 cm down to ±1mm, and have a rapid time response.

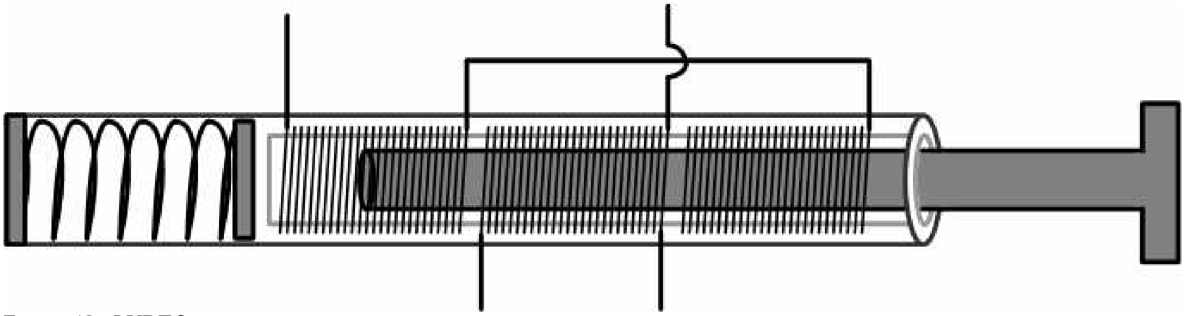

FIGURE 12 – LVDT STRUCTURE

CONCLUSION

This work shows part of the efforts developed on Unicenp´s Engineering courses to enhance students learning experience. These experiments related here are going to be used in this season. Results are been carried out and are going to be shown on ICEE. It would be empathized that preliminary ones shown in a direct way an achievement on the ability of the students on observe, relate, describe an, by extrapolation, predict additional conclusions about the physical phenomena related here.

These experiments are not expensive (once the use of the computer is common in laboratories) and very easy to build, so, the application of them is very direct and productive in order to enlarge students´ learning experience.

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