A Proposal for an Experimental Approach of Vectors

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Abstract. *In this work, we promote a proposal for a laboratory exercise, for the familiarization of students with vectors. This exercise is based on the composition of forces and the calculation of the resultant, but also on the analysis of forces in their components, depending on the level of application.*

The exercise asks students or teams of students to find the unknown weight (mass) of a body, with the use of a line of known weights (masses), threads and pulleys. It is assembled as a construction of balancing three forces of which only two are known. The forces are portrayed in a piece of paper as directions and then are drawn under scale. Then the third force is calculated as the resultant of two known forces. The corresponding application with analysis of forces uses, besides a protractor for the measurement of the angles, trigonometric numbers for the calculation of components.

Keywords. Vectors, Science teaching, Self made experimental apparatuses.

1. Introduction

In previous articles [1], [2] we have reported on the value of laboratory applications, based on self made experimental apparatuses, made of simple materials, for quantitative measurements using polymorphic experiments [3]. The present work is an experimental application with mentioned characteristics, in the comprehension of a difficult concept for the students, the vectors. A number of references [4] [5], confirms that a concept like the concept of *vector* has two components. The mathematical concept (algebraic and geometric) of the *vector* and a physical concept (representation) that connects vectors with science applications. For the second component, absence of simple experiments connecting directly the concept of *vector* with the measurement on a natural phenomenon is observed). For the natural phenomena that require the use of vectors, the mathematization is done without the participation of the student and without any direct connection to natural experience.

The experiment we propose, prepare the student for the connection between the mathematic and physical representation of vectors. Also the students are trained to discover the sources of the errors through the knowledge of the physical phenomenon. At the same time it constitutes an exercise for the significance of unit of measurement, the use of proportions and the use of trigonometric numbers in practice. From the application of the experiment, they may acquire a series of psyhomotive skills, the fineness of handlings that require the experimental provision, the drawing of parallels and the accurate measurement of lengths. The results on each step, constitutes an important experience of self-assessment for the students.

2. Methodology

The experimental application is based on a common exercise that the students are called to solve. To calculate the resultant of two forces, using either the rule of parallelogram or with the rule of triangle. This particular exercise can function on a very simple way as a laboratory experiment. The experiment consists on the question “what is the weight (or mass) of a body” with the use of threads and pulleys and known weights (masses). The students have to construct an experimental apparatus as in **Scheme A**. With the use of two pulleys and threads and two known weights, conditions of balance of three weights are created with the unknown weight as one of the three. With a piece of paper behind the threads they make an imprinting of the directions of the threads with special attention to not disturb the balance of the system.

Based on this imprinting, they can start the process of calculation. The first control that the students can run in order to evaluate the precision of imprinting, is to produce the directions of the three lines up to meet each other at the same point. In case where the divergence is big, it will be supposed they have to repeat the imprinting. The effort of a precise imprinting requires accurate handling and develops psyhomotive skills to the students. Then they

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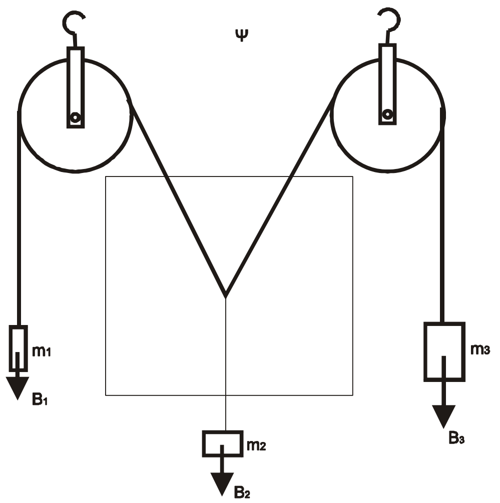
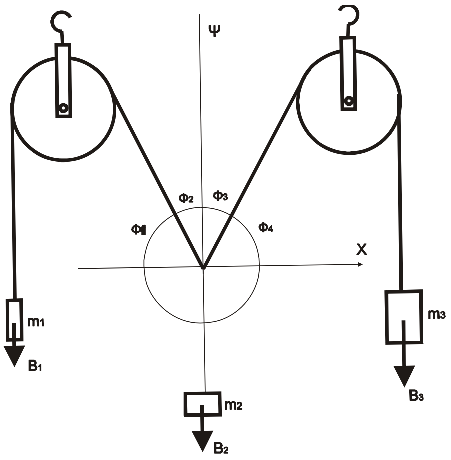
have to design in scale the two known forces. At this point the significance and the use of unitary vector become perceptible. Then with the use of a parallelogram or triangular they design the resultant of the two forces. The design of a parallel helps in the acquisition of kinetic skills of the students and the understanding of geometrical terms. At this point, we have a second self-assessment, while the resultant of the two forces should be on the same rule line with the third force. Whoever, divergence shows a fault either on the design of the parallel, or in the imprinting of forces with base the unitary vector. Finally, based on the unitary vector, they calculate the third force.

Such an experiment is appropriate for students of the second and third class of the High School. According to the analytical program, the students in Greece meet for the first time the mathematical and physical concept of vectors. The experiment is also useful for the students of the pedagogic departments in combination with the next experiment, as it works as a polymorphic experiment.



Scheme A

A version of the above experiment, that is appropriate for Lyceum and Pedagogical department students, is to place at the centre of threads, a protractor or its photocopy. With the system balanced, we turn the protractor suitably to fix a system of axes, with axis X horizontal and axis Y vertical, in order to overlap with the thread of B2 (**Scheme B**). This helps the students, to become familiar with the usefulness of the freedom on the choice of axes. Then we can follow two ways. On the first way, they imprint the directions of the forces, based on the measurable angles on a piece of paper and develop the experiment as it was described above. On the second way, they are analyzing the forces in horizontal and vertical components, so students practice themselves on the balance of the components of the forces in every axis. In this application we have to mark two fundamental points; a/the weight of protractor has to be added on the B2 weight and b/we decrease the psyhomotive activity of the students and some stages of self-monitoring of the application (but it gives the opportunity to exercise with the trigonometric numbers and the analysis of vectors in components).



Scheme B

3.Epilogue

We applied the above described experiments on students of Department for Primary Education of the University of Crete and on students of second class of high school. The students of high school worked pleasantly in small teams. They had a better comprehension of the concept of vectors. The second version was faced pleasantly by the students of our laboratory and showed to help to the physical application of a mathematical concept. The self-assessment that is also included in both experiments is pleasant for the students and they assist in the effort of a spontaneous self motivation. The analysis of the errors helps on the comprehension of individual effects caused by the parts of system as pulleys friction or what affect the precision. They were able to locate both, the systematic errors but also their handlings errors, the random errors.

9. References (and Notes)

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[3] Polymorphic teaching in Science and Technology includes a common psychomotive activity (e.g. constructions, measurements, experimentation ...) which consequently is morphed into different education levels depending on the (previous) cognitive attainment and/or the mentality of the students. It resembles 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 teachers to the subjects they are going to teach in school where there is a requirement of teaching in an advanced level for the teachers themselves and teaching in a level more accessible for the pupils. See more in 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).

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