VIDEO-MEASUREMENTS IN PHYSICS TEACHING

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ABSTRACT
Videomeasurements of different kinds of motion can be a useful tool to help understanding of concepts and laws of motion. In the article there are examples of designed videoclips and videomeasurements of different situations presented. Videoanalysis of the physical situations is realized with a help of IP COACH system. There are also instructional materials aimed at student active learning using videomeasurements described.

KEYWORDS
Video-measurement, videoclips, videoanalysis, IP COACH system

INTRODUCTION

Mechanics belongs to the first topic high school students as well as University students come across during their physics lessons. There are many tools available in aid of teaching of mechanics. Using modern computer tools in this field seems to be very effective. One of them is real-time measurement in microcomputer-based lab where students can measure position of a moving object and process and analyse the gained data. Another possibility is to use computer tools to measure on the ready made laboratory-based or "real world" video clips. Furthermore, the gained data presented in graphs can be analysed and processed. Such an activity can bring positive influence on the students understanding of mechanics concepts (Beichner, 1996; Ellermeier, Landheer, Molenaar,).

WHAT IS A VIDEO-MEASUREMENT?

Real physical experiment plays an important role in physical science as well as in physics teaching. In the process of teaching physical experiment can play different role. The experiment can be presented either in order to discover a physical law or behaviour of certain object or it can prove a previously explained physical relationship or law described theoretically. In both mentioned cases a teacher in front of the whole class can realize the physical experiment or students themselves in pairs can do measurements in a so-called laboratory activities or lab works. However, in real process of teaching a teacher can sometimes be in a situation when the equipment of physical lab does not allow realizing the proposed experiments or the accuracy of measurements is limited. Another accessible possibility for a teacher as well as for students is to realize real-time measurements on video-clips prepared in advance. The videoclips can be recorded beforehand or there is a wide choice of videoclips accessible on the web. Videoclips appropriate for educational reasons can be as follows:

- ♦ Videoclips of different physical phenomena that can be realized in a physical laboratory with difficulties because of technical reasons, expensive tools or long time needed, limited accuracy, etc.
- ♦ Videoclips of different situations referring to everyday life, that are highly attractive and interesting for students, e.g. motions of runners, means of travel, roller coasters, sport activities like jumping, running, throwing balls, collisions, etc. Presenting these well-known situations from every-day life can be very motivational for students.

There is a wide choice of different software products offering the possibility to collect data from videoclips. One of the software products available in this field is a Dutch computer learning environment called IP COACH. IP COACH is a complex system enabling different kinds of activities, i.e. real-time measurements, creating dynamical models, data processing as well as video-measurements. With a help of last-mentioned tool we can do video-measurements of position of a moving body, as well as velocity or acceleration consequently. The results of measurement can be recorded and displayed in a diagram. Furthermore, these diagrams gained from real measurement realized on a videoclip of real situation can be processed and analysed and the relationship between physical quantities can be proved or discovered.

EXAMPLES OF VIDEOMEASUREMENTS

Existing or recorded videoclips can be used for the purpose of carrying out individual practical investigation tasks. In this sense video-measurement can be set as an activity similar to lab work where students work in pairs or individually in order to investigate or explore the world around them. The only difference is that the measurement is executed on a videoclip. Student following the tasks on the working sheet goes step by step through the activity doing measurement itself and the analysis of gained data consequently. There are several different activities designed as examples of a proposed use of this kind of activity in physics teaching at high school or University level.

VIDEOANALYSIS OF MOTION IN THE PRESENCE OF RESISITIVE FORCES

When talking about motion in a straight line and its mathematical description, high school physics describes just two kinds of motion, i.e. uniform (no resulting force acting on the body) and uniformly accelerated motion (constant force acting on the body) in ideal conditions without any resistive forces acting on the moving body. But the real situation we come across every day is rather different. Every object in motion is always under the influence of resistive forces that can make the motion more complicated and difficult to describe mathematically. With a help of the mentioned tools different kinds of motion under the influence of resistive forces can be explored.

Example 1: motion of different spheres falling in oil

This is a standard example of motion when the resistive force is effectively modelled being proportional to the sphere's velocity. This fact can be examined with a help of data-video tools of IP COACH system where we measure the position of a falling sphere presenting the position vs. time diagram as well as velocity vs. time diagram. The beginning of the motion is complicated with changing acceleration but finally the sphere reaches its terminal speed. From the diagram of position vs. time (fig.1) it can be seen that the initial part of the motion with growing velocity is very short and the motion is uniform with constant velocity. Knowing the diameter of a sphere and properties of oil we can set a theoretical model describing this kind of motion (table 1).

Table1. Theoretical model of the motion of a sphere falling in oil

- $t=t+dt$
- $F_o=6\pi r\eta v$
- $a=(F_g\text{-}F_v\text{-}F_o)/m$
- $v=v+adt$
- $x=x+vdt$

r=0.00395/2	'm, radius of sphere
η=4.5	'N.s/m^2, viscosity of oil
g=9.81	'm/s^2 gravitational constant
m=0.00425	'kg, mass of sphere
$V=(4/3)\pi r^3$	'm^3, volume
ρ_{oil}=1040	'kg/m^3, density of oil
$F_g=mg$	'N, gravitational force
$F_v=V\,\rho_{oil}\,g$	'N, buoyant force
x=0 : v=0	'initial position, velocity
t=0: dt=0.001	

Total force acting on the sphere consists of gravitational, buoyant and resistive force. In this case the resistive force $F_0 = 6\pi r \eta v$, where *r* is a radius of a sphere, *v* is its instantaneous velocity and η is a viscosity of fluid. Presenting both experimental and theoretical results and simulating the model for different viscosity the appropriate viscosity of oil can be found. From the diagram good correlation between experimental and theoretical results can be seen (figure 1).

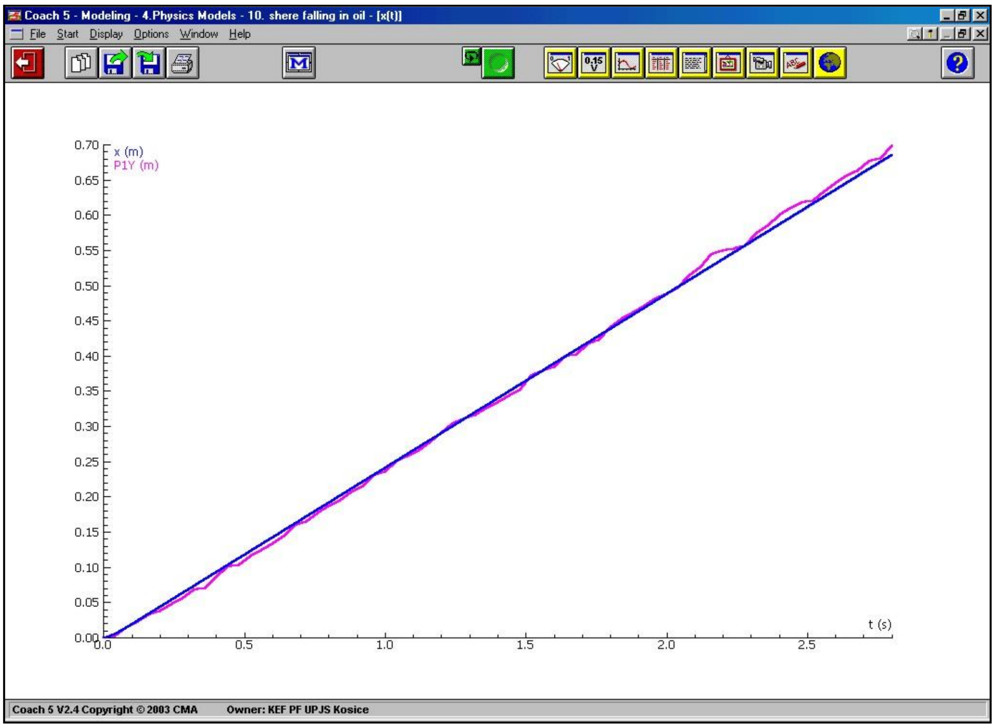

Figure 1. Experimental and theoretical results of the motion of the sphere falling in oil

VIDEOANALYSIS OF ROTATIONAL AND TRANSLATIONAL MOTION OF A BODY

Example 1:

When an object (e.g. a sphere or a cylinder) rolls on a surface, its motion is rather complicated. The centre of mass moves in a straight line, but a point on the rim moves in a more complicated path. The rolling object motion is composed of translational and rotational motion. This fact makes a problem of a body rolling down an incline quite complicated. The reason is that the initial potential energy at the beginning when the body is in rest is gradually changing into kinetic energy of the rolling object that in this case consists of translational and rotational kinetic energy. That's why the acceleration gained by the object is smaller than that of sliding down without any friction and rotation. The acceleration gained depends on the moment of inertia of the object, in the case of sphere we get $a = \frac{5}{7} g \sin\alpha$, where α is the angle of the incline. This result can be tested experimentally by measuring position, velocity and acceleration of different spheres of different diameters and masses. The result of video-measurement of a shere rolling down an incline of α=9^o is in fig. 2. In fig. 3 there is a position vs. time graph fitted by quadratic function. Doubled the coefficient *a* of the quadratic function we gain the acceleration that is about *a* = 1 m.s^{-2}.

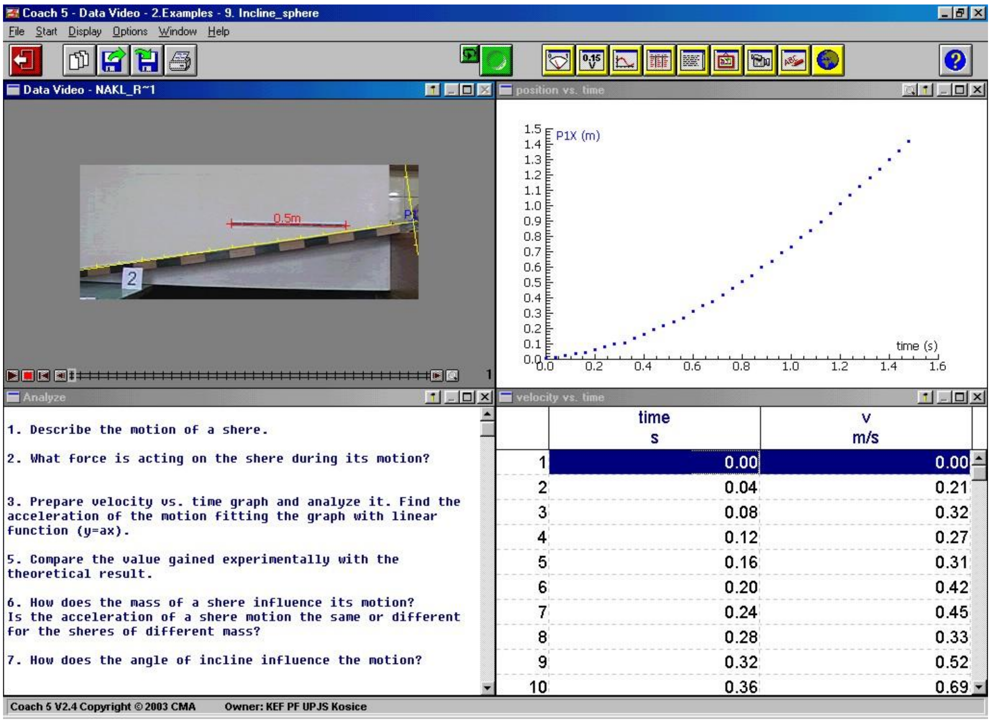

Figure 2. Result of video-measurement of position, velocity and acceleration of a centre of mass of a sphere rolling down an incline of α=9°

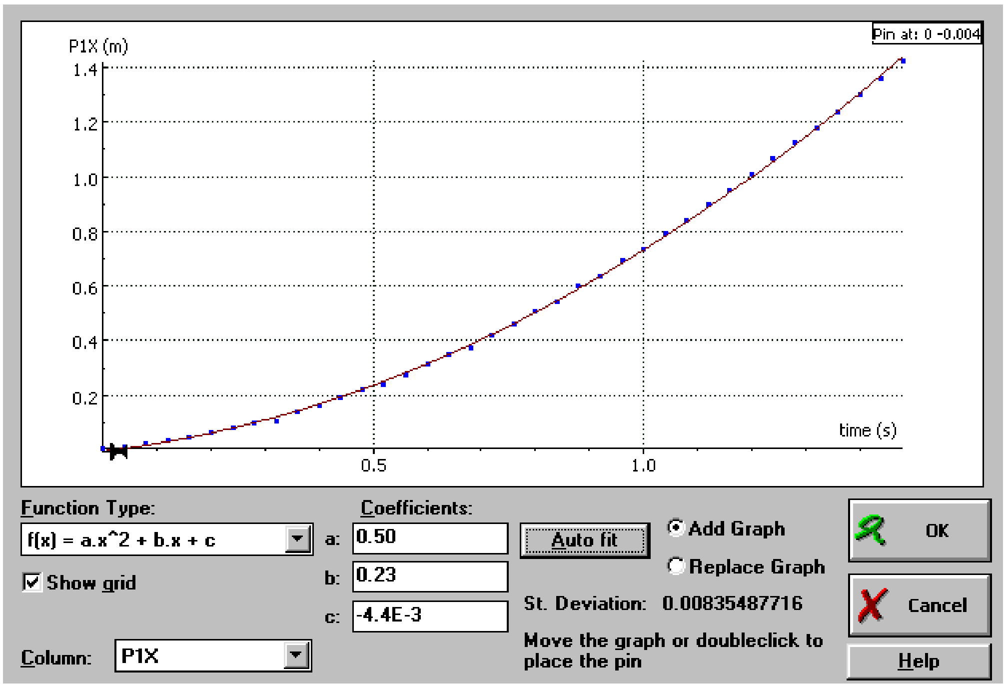

Figure 3. Fit function of position vs. time graph

Example 2:
Another interesting problem in rotational dynamics is a motion of a uniform disk with a string wound around it known as Maxwell flywheel. The disk is released from the rest with the string vertical and its top ends tied to a bar. As the string gradually unwinds, the wheel descends with uniformly increasing velocity. In this case several questions turn up to be answered by the students:

- What is the influence of different mass (same radius) on the motion?

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- What does the acceleration of the disk depend on?
- What is the law of conservation of energy like in this case?

The answers to these questions can be found exploring the motion with a help of video-measurement. Measuring the position and derivating its time dependence the acceleration of motion can be found. Knowing the moment of inertia of the disc the experimental value of acceleration can be compared with the theoretical one. Furthermore, potentional and kinetic energy (rotational and translational) can be calculated in each moment of the motion to check the validity of the Law of conservation of energy. The example of measurement is in figure 4.

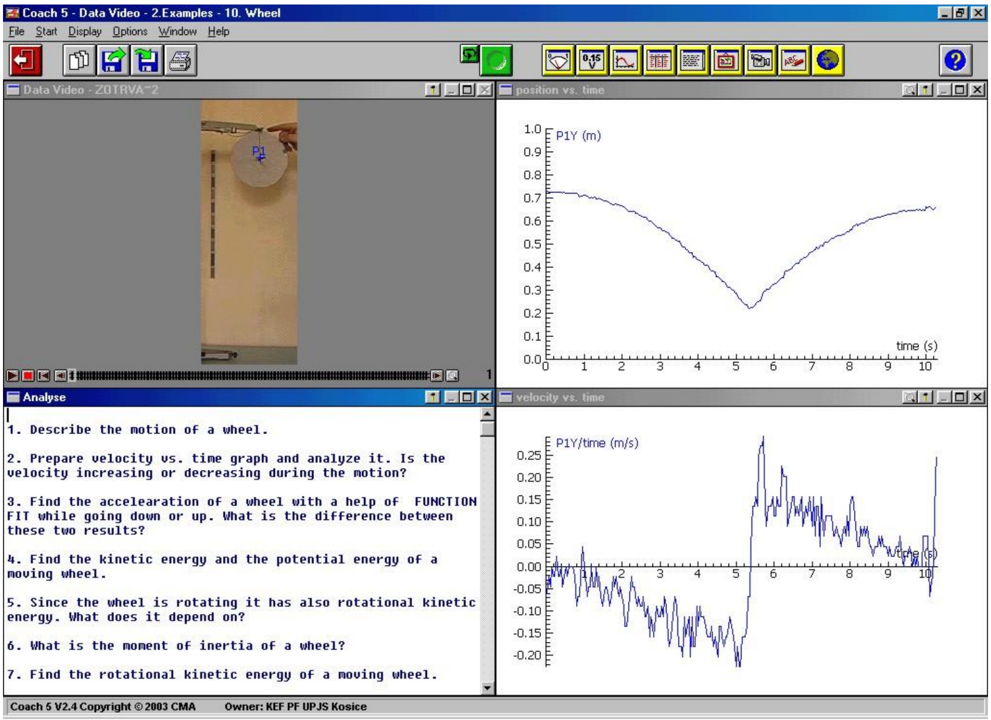

Figure 4. Result of video-measurements of position and velocity of the centre of mass of a moving disk.

CONCLUSIONS

In the contribution we tried to show a few examples how to use videoanalysis in physics teaching. Videoanalysis in physics teaching can become very effective since it offers a simple tool how to analyse different kinds of motion or other situations in details. As the measurement is realized the position on the object as well as its time dependence on the graph is simultaneous. That is the same while observing and analysing the graph after measurement. This fact can surely help in interpretation and understanding of graphs and can deepen the knowledge about analysed situation. Video-measurements provide students a tool that can help not only in the study of lab phenomena (presented here) but also real world situations (Beichner, 1996; Ellermeijer, Landheer, Molenaar, 1996). Students are given opportunity to play back the motion to make sure they understand the critical aspects and help focus their attention to those where there are misconceptions. Presenting and analysing attractive real world situations can also help to motivate students and make physics more interesting.

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