Active Learning Approaches by Visualizing ICT Devices with Milliseconds Resolution for Deeper Understanding in Physics

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Abstract. We are developing various modularized materials in physics education to overcome students' misconceptions by use of ICT, i.e. video analysis software and ultra-high-speed digital movies, motion detector, force sensors, current and voltage probes, temperature sensors etc. Furthermore, we also present some new modules of active learning approaches on electric circuit using high speed camera and voltage probes with milliseconds resolution. We are now especially trying to improve conceptual understanding by use of ICT devices with milliseconds resolution in various areas of physics education We give some modules of mass measurements by video analysis of collision phenomena by using high speed cameras—Casio EX-F1(1200fps), EX-FH20(1000fps) and EX-FC100/150(1000fps). We present several new modules on collision phenomena to establish deeper understanding of conservation laws of momentum. We discuss some effective results of trial on a physics education training courses for science educators, and those for science teachers during the renewal years of teacher's license after every ten years in Japan. Finally, we discuss on some typical results of pre-test and post-test in our active learning approaches based on ICT, i.e. some evidence on improvements of physics education (increasing ratio of correct answer are 50%-level).

Keywords: Active Learning, Devices with Millisecond Resolution, Students' Misconception.
PACS: 01.40.Fk Research in physics education

INTRODUCTION

We are developing various modules on Newtonian mechanics in frictionless world by use of super-light cart-fan systems, toy hovercraft (hover-soccer or hover-hockey) systems etc.[1] We are also making various modules on laws of motion in frictional world (in air or in water) having terminal velocity by use of super-light-paper cup systems [1]. By use of these modules for active-based physics education, we have provided courses of remedial physics in mechanics [2]. Recently, it becomes very convenient to use various cheap ICT devices having milliseconds resolution, such portable high speed camera as Casio EX-F1, EX-FH20 and EX-FC100, and also various ICT-sensors for science education. Thus, it is highly expected to develop active learning physics new modules based on various ICT tools with milliseconds resolution [3].

In Figure 1, the results of recent evaluation [4] on Japanese teacher's feeling of satisfaction in performing

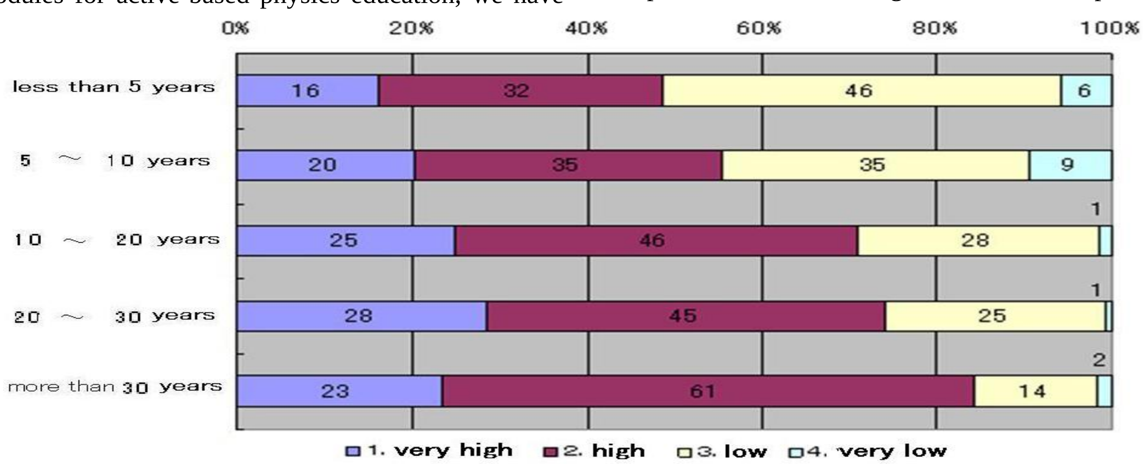

FIGURE 1. Teacher's feeling of satisfaction in performing physics education.

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physics education are shown. About 50% of young teachers less than 10 years of experience have low satisfaction in performing physics education and in using ICT-tools in physics education research [4].

Therefore, it is very important to make physics education more attractive and more interesting ones by use of very convenient and attractive ICT devices with milliseconds resolution such as portable high speed camera and sensors [3], to get deeper conceptual understanding of collision phenomena and so on.

Here we present our special effort to promote ICT-based active learning modules [5-7] by use of milliseconds resolution devices, such as high speed movie camera and various useful sensors [5-7].

Now we are also trying various educational usages of these ICT-based modularized materials in core science teacher programs of Faculty of Education, Niigata University, and also in ILD (Interactive Lecture Demonstration [7]) on Newtonian Mechanics to middle school pupils and high school students of Niigata and also to students of Niigata University. And we are also testing these ones in training of science education skill for teachers of Niigata (2003-2009). Furthermore, we are undergoing various ICT-based active learning courses in physics education for renewal of teacher's license (2008, 2009) [3].

VISUALIZATION OF MILLISECONDS WORLD BY NEW ICT DEVICES

Recently, we are trying to provide various modularized materials by use of ICT devices with millisecond resolution such as high speed digital movies, and various sensors, current and voltage probes, temperature sensors etc. in physics education to overcome students' misconceptions. [3,6,7]

Visualization of molecular motion of Kinetic Model for Gas

Firstly, we present an analysis of a visualized molecular motion using high speed camera movie of a kinetic model for molecular motion of gas.

We show a photograph of cylinder type equipment in Fig 2, i.e. a model for molecular motion of gas. One frame of the movie, which is taken by high speed camera, as shown in Fig. 3. Those movements of the small steel balls in the cylinder are just a good animation of molecular motion for the kinetic theory of gas. In Figure 3, we show a typical velocity versus time graph obtained by video analysis with LoggerPro software[5] for small steel balls in the cylinder. It is noted that the faster at bottom (right side of the cylinder) and the slower at top (left side of it), because the steel ball is accelerated by gravity force, as shown in the v-t graph of Fig. 3. This example shows that it is very convenient to visualize by high speed camera with 1000-1200 fps (frames per second) to get deeper conceptual understanding in molecular motion for the kinetic theory of gas, but it's too fast for naked eyes or even for 30 fps movie camera it's difficult to see clearly every motions of steel balls.

We can also get visualization of guitar sounds by seeing clearly the vibrations of the guitar strings with the slow motion movie of high speed camera as Casio EX-F1 etc.

FIGURE 2. A kinetic model for molecular motion of gas.

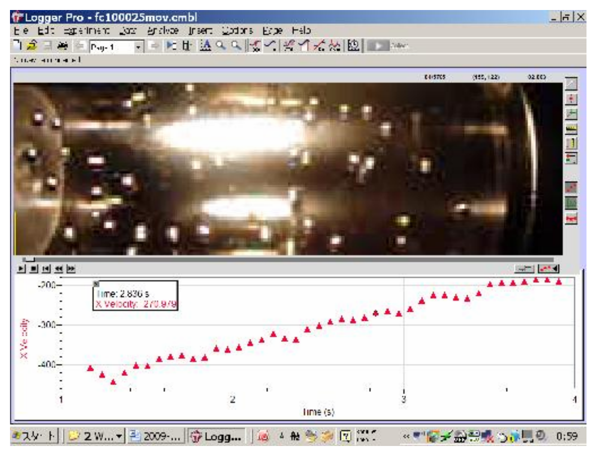

FIGURE 3. Typical movement of a small steel balls in this photograph of cylinder are shown by v-t graph in bottom.

Also we have presented various visualization of milliseconds world of various wave phenomena such as the standing wave phenomena of strings connected to a vibrating jig saw machine. Furthermore, we can visualize electric currents, to get new active learning modules by high speed camera, current and voltage probes for deeper conceptual understanding of electric circuit phenomena. [3] We made a typical module to measure mass of air in big-balloon-pendulum with water-balloon-pendulum by analyzing digital movies of collision. However, we must skip all of those by the limitation of space of proceedings for our talk.

Collision Phenomena of Pendulums Visualized with Milliseconds' Resolution Using High Speed Digital Movies

In 1650, "Two Pendulum collision laws are ruled by the principle of leverage" had been found by Huygens. That means "the position of CM (center of mass) of two moving balls of the pendulum" is invariant in the pendulum collision processes. Therefore, each ball's distance from CM is inversely proportional to each ball's mass value.

From Huygens's principle of leverage for two pendulums, we find new attractive active learning modules by use of CMS (center of mass system) pendulum collision idea. Now we present several active learning modules on the momentum conservation rule using collision in various pendulums systems, which include some typical educational usage of high speed digital movies analyses for collision in milliseconds' world. It is noted that to find a way getting easily a CMS for two pendulums with various weight is essentially important as shown in Fig. 4, where special mass ratio m/M = 1/3 is presented.

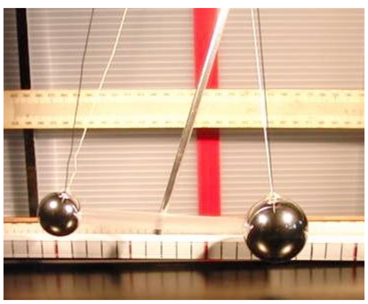

FIGURE 4. Typical CMS for two pendulums.

We always realized easily CMS collision phenomena for any two types of pendulums by putting a straw between two balls which stabilize two balls in CMS with suitably separated positions. And we can determine the mass ratio from the "Huygens's principle of leverage", i.e., each ball's displaced distance in CMS is inversely proportional to each ball's mass ratio anytime as shown in Fig. 4.

Here, it is noted that using milliseconds resolution of high speed camera we easily get the detailed information of each ball's displaced distance in CMS. Therefore we can easily get the precise mass ratio of each pendulum as shown in Fig. 5, where vertical line show the distance from the lowest colliding point (lcp). Each ratio of left and right distances from lcp is 3.00 for three cases in Fig. 5. Thus, two body pendulums collision in CMS is excellent method for precise mass measurements. Figure 6 show the typical Video-Point [5] analysis for the same elastic two body collision.

As shown in Fig. 6, we get x-t graphs (upper ones) and v-t graphs (lower ones) by Video-Point [5] analysis for the two steel ball's movement for 2 body pendulum collision. These graphs indicate that every ratios of moving distance and velocity ratios for two balls are always inversely proportional to each mass ratio, for example the mass ratio m/M is 1/3.

Here we show some examples of Q&A (Questions and Answers) in typical active learning modules for various collision phenomena of 2-body pendulums collision in CMS with milliseconds' resolution movies.

- What is the meaning of "the principle of leverage" in this pendulums collision in CMS?
- Determine the ratio of magnitude x of two balls for any t from x-t graph？
- Determine the ratio of magnitude x of two balls for any t from v-t graph？

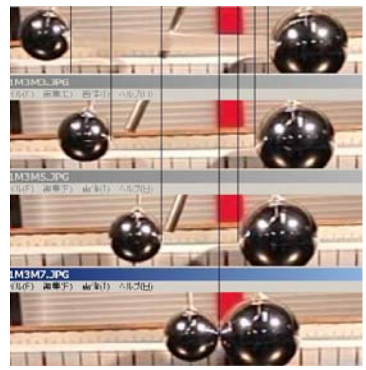

FIGURE 5. Typical way to get each ball's displaced distance in CMS, and those of to get each ball's inversely mass ratio of 2-body pendulum in CMS.

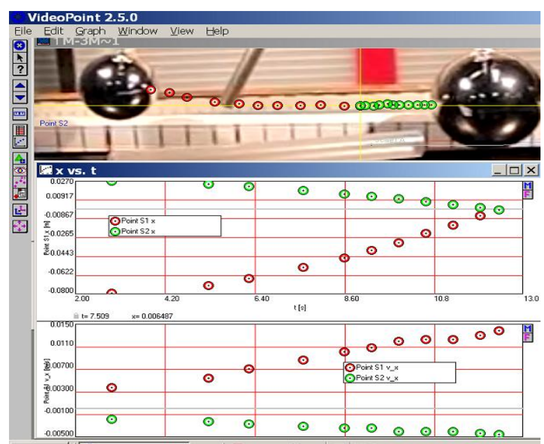

FIGURE 6. Typical Video-Point analysis for the movie of the high speed camera, i.e. x-t graphs (upper ones) and v-t graphs (lower ones) of the two steel ball's for 2 body pendulum collision in center of mass system.

Analysis of high speed movie of two body pendulum systems made of various materials

Now, we discuss on the two-body pendulums in CMS collisions made of various materials.

Firstly, we present an analysis for the case of 2-body pendulums of each is made of steel and brass materials. Figure 7 is a mass-ratio-measurement of the two same-size-balls made of steel and brass.

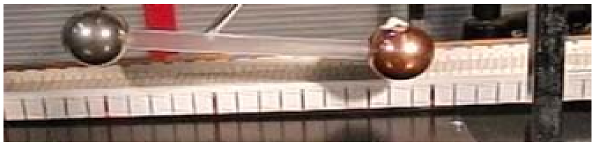

FIGURE 7. Movie of high speed camera for 2 body pendulums (made of steel and brass) collisions in CMS.

Secondly, we present an analysis for 2-body pendulums made of aluminum and steel materials. Figure 8 is a mass-ratio-measurement of the same size two balls made of aluminum and steel.

Thus, in CMS collision, we can easily find out the mass ratio in comparison to laboratory system; i.e. steel and brass pendulums collision in CMS.

Now, let's measure the relative density between various two different materials by such 2-body pendulum collisions, but we skip detail analysis.

Continuous Collisions of Newton's Cradle (Executive Ball Clicker) in CMS

In Figure 8, we show one frame of movie of one type of continuous collisions (2 balls-3 balls) for "Newton's Cradle" in CMS, these system is placed on frictionless glass beads board, that is, the Newton's Cradle system never move on the frictionless glass beads board known by seeing slow motion movie.

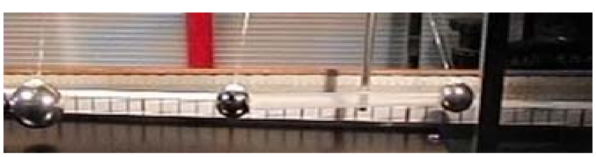

FIGURE 8. The movie of high speed camera for 2 body pendulum (made of aluminum and steel) collision in center of mass system.

That is why the CM for the two pendulum-balls system is invariant in all times of collision. In the case of "Newton's Cradle", we get always a countable mass ratio and we also get the same magnitude of momentum, but opposite sign.

Let's investigate continuously collisions in CMS for such cases of two groups of n-balls-pendulums as, 1ball-1balls, and 1balls -2 balls, 1balls – 3 balls, 1balls -4 balls, 2 ball – 2 balls, 2 balls -3 balls, etc. but we skip details of these analysis.

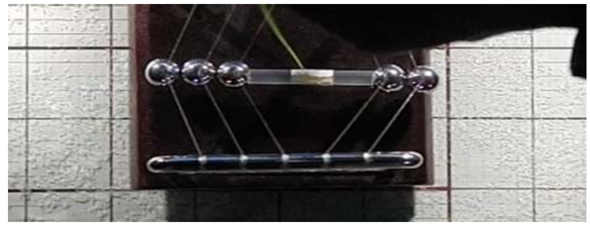

FIGURE 9. The "Newton's Cradle" in CMS on frictionless glass beads board.

CONCLUDING REMARKS

1. We get New ICT-Based modularize materials, i.e. visualized in milliseconds world, which increase the conceptual understanding and are effective for the development of science education.
2. We obtain many new modularized materials, i.e. pendulum collision in CMS, and such materials for active learning are shown to be reasonably useful in both frictionless and frictional world [1].
3. It is very important to promote ICT-based science education for middle, high school pupils, students and also teachers for renewal of license.
4. By effective usage of ICT-based education in mechanics, we increase the correct answer ratio from 30% level (Pre-test) to 80% level (Post-test) [1,5,6].

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