

# visualisation of physics in school

Problem-orientated animations for education purposes.

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March 1, 2012

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## Introduction

While teaching and learning scientific subjects such as math, physics or chemistry in schools, both – pupil and teacher – need to have a high level of property in abstraction- and interpretation-skills; in order to be successful in what they're doing. A big problem in this special case of teaching *scientific* subjects is the (possibly) existing aversion by students against those subjects. But this disinclination does not *just exist* individually before covering a certain topic; there has to be an origin of this aversion. My job as a "teacher-to-be" is to locate the source of those aversions, and to intervene there. This is mainly important because without such an intervention at this point, a little misunderstanding in a certain fact in whatever subject from above, could lead to bad results or ongoing misunderstanding of following facts covered in that class, which – with a high possibility – will lead to a loose of interest in the lectures, as well as inattention and inactivity during class. Finally, other things will not be understood well by pupil; and even worse, if failed in a high quote of tests, this could lead to a

dangerously high aversion for scientific subjects in general.

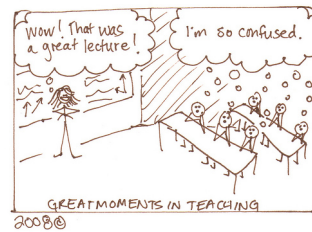


Figure 1: non-understanding caused by ignoring pupils problems

But the good thing here is, that the teaching person absolutely can avoid such situations. This requires both – *commitment to listen* to pupils and a skilled sense of *locating possible problems*.

## Purpose

First and foremost, for teachers the last point can be trained. A big problem in teaching physics is the high dependency of (frequently occurring) physical *models*. Here, *model* means a construct of thinking, a theory, which make it possible to understand how things in the world work. Such

a model concentrates on essential facts, which are necessary to understand a working system. Examples are all the models of atoms, the model of elementary magnets, center mass, light as a wave or light as a particle. Important is, in all cases a model is just an approximation to the real world, which describes things properly in the planned purpose; but all models have borders and are not reality.

Very often, you cannot understand working physical systems without using suitable models for explain various phenomena (e.g. physics of atoms and quanta, physic of optics). The problem with those models is the (first look appearing) variation from the world, how pupil see it. Or pupil completely misunderstand a certain model in a way, that it would affect their continuing learning process.

In order to detect and get rid of these (possibly) appearing problems and misunderstandings, good teaching materials, that give pupil a proper concept of physics, are needed. Unfortunately, the use of modern media in education still is manageable. However, I believe that using modern media, such as computers, can certainly make enormous progress in learning. Drawings and figures in books are an appropriate way to underline some aspects of physical concepts too; but in fact, in some cases, like behaviour of waves or rotation movements, a nice animation can explain things better and more intuitively. Animations are gaining an edge over pictures in a lot of cases, for example when it comes to 3-dimensional problems or explanations concerning chronological sequences. More advantages could be found easily.

My goal is to create those animations, in order to give pupils good support during their learning periods in daily school life. I hope this will help to decrease (possibly ex-

isting) aversions against scientific topics in school, will help them to understand complex elements of science better and increase their own level in that subjects.

## Method

With using *POV-Ray* and *Giam*, I'm able to make those kind of animations for teaching purposes. *POV-Ray* is short for the Persistence of Vision Raytracer, a free software for producing high-quality computer graphics. The "problem" of *POV-Ray* is, that it can only produce pictures, but no moving animations. For that purpose I use the also free program *Giam*, with combines the previously produced pictures to a GIF-animation (GIF stands for Graphics Interchange Format; files in this format can be easily watched in internet-browsers). You can find these animations on my website<sup>1</sup>, by clicking the "Pov-Ray"-section. By opening the information on the web, any people can see, modify and even create new models.

With *POV-Ray* made animations cannot be changed afterwords. So it's not possible to change some variables in it, in order to see the effect of that change. This may appear as a contra, but in the same way it is a con, it's also a pro: So pupil get focused on the important points of the problem and aren't able to "play" around with the program. So the teaching person has the full control over it. In order to understand which changes would take effect in a certain way, pupil need to understand the problem qualitative and quantitative. The animation in this case can be also seen as a motivational introduction to the covered topic.

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<sup>1</sup><http://flex.phys.tohoku.ac.jp/~florian.simon/>

I've created several GIF-animations, related to the kinematics part of high school education (elastic collision, translational and angular momentum conservation, energy conservation). All those animations are fully functional and ready to use in school life.

An detailed example: Even if the concepts of translational and angular momentum conservation are understood nicely, the combination of the two can be quite difficult to pupil. For example imagine what happens, if a hockey-puck will hit a wooden bar laying on ice. In order to make understanding more easy and intuitively, I created several animations to that problem.

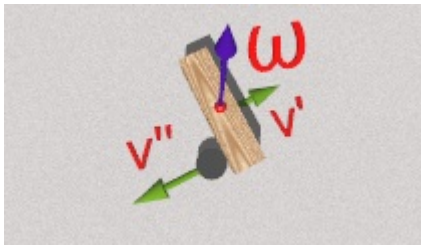


Figure 2: A puck impacts a wooden bar on ice.

The animation to the picture seen in Fig. 2 shows a (vertical laying) wooden bar on ice which is hit by a puck (constant, linear-horizontal movement, elastic collision). I've chosen ice as ground for approximate non-friction surface. The first sequence in this animation is the case, that the puck is hitting the center of the bar; so that no rotational movements has to be considered (pupil should know this case). Then the puck changes position and moves again in the same way towards the bar.

The animation pauses at the beginning and the time of the impact and (labelled) vectors for velocity and angular momentum appear. Those vectors are very important for understanding quantitatively. So

you can see easily, that after the impact, the puck is moving back in the exact opposite direction as it came, the center of the wooden bar is moving in the same direction as the puck before hitting the bar and the bar gets some angular momentum around the center of it. In order to recognize this movement more clear, I put a little red dot above the center mass on the surface of the bar, so pupil can follow the movement of the center more easy. The reason why the *center* of the bar is moving with constant velocity in this direction and the bar also rotates around the *center*, is because in this case the *geometric* center is also the center of *mass*. Furthermore, after the hit, I put in a trace of the moving bar. By that, you can see the center is moving linear and with constant velocity, because the distance between the "traced wooden bars" is constant; as seen in Fig. 3.

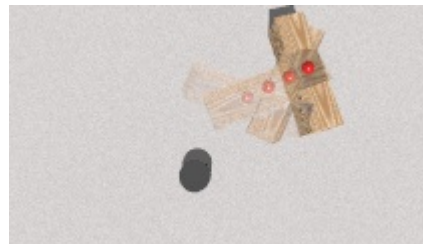


Figure 3: The "traced" wooden bar with red dot above the center of mass.

In this chronological sequence, students can see the effect of an impact like this, and in the same moment, it's possible to understand *why* the movement has this shape, because of the pause and the appearing vectors. After the hit, you can see the movements itself, and in the same moment, recognize that the bar does a combination of a linear movement with constant velocity and constant rotation. This immersion of *watching, recognition* and *intuitive understanding* cannot be reached that easily with

just one picture or graphic.



Figure 4: A special case that the bottom velocity is eliminated.

The animation shown in Fig. 4 shows the impact on different points at the bar in a way, so that the bottom velocity is eliminated. This point depends on velocity and mass of puck and bar.

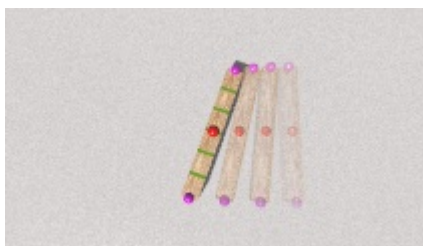


Figure 5: In this case bottom velocity doesn't change.

The animation shown in Fig. 5 shows the impact on a point of the bar in a way, so that the bottom velocity doesn't change. This point does *not* depend on velocity nor mass of puck or bar. This knowledge can be used for determining the so called "sweet spot" of a tennis racket<sup>2</sup>. The equations are a different, compared to the puck or a real tennis racket, but the principle is the same.

In this last figure you can see a snapshot of a animation of a tennis racket hitting a ball on the "sweet spot". In this case, the



Figure 6: The sweet spot of a tennis racket.

tennis racket consists of a cylinder (handle) and a ring with net; the center of mass is located at their touching point. The radius  $r$  of the ring and the length of the handle  $l$  are equal to each other. The "sweet spot" does *not* lay in the center of the net, even if it may look like it. The point is located  $\frac{5}{18}r$  below the center of the net.

This last animation (Fig. 6) represents one possible way of using the covered things for solving real-life-problems, and can be also shown as a motivational introduction to the topic and/or the closing of it.

<sup>2</sup>The "sweet spot" here is the point of hit, where impact shock and vibrations are optimally subdued.