GeoGebra for Secondary School Physics

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Abstract
GeoGebra is a free software which has wide possibilities of using at secondary schools. In math lessons it is obvious. Using of GeoGebra for teaching the geometry and the analytical geometry is maybe an easiest way how to utilize this software. However, GeoGebra also offers tools for the calculus, the statistics and animations. All these facts suggest that we can use GeoGebra in physics. We can work with coordinates and vectors, we can simulate physical systems which are depended on a time and show their evolutions through animations. Then, using of the calculus and statistics in physics is a matter of course. We can also use interactive tools and create our own applets. A great advantage of GeoGebra is that basic tools are intuitive and simple to use. Thanks to this fact GeoGebra has lots of users around all world and they share materials ready to use at schools or instructions how to use some certain tool. This paper shows some of possibilities how to use GeoGebra at physics lessons.

1 Basic Possibilities of GeoGebra in Education
GeoGebra is sophisticated application which we can use in school at math lessons but also at physics lessons. In short GeoGebra is a dynamic mathematics software which can be used for an education of geometry, algebra, statistics, calculus etc. (GeoGebra – about, 2017). Possibilities how to use GeoGebra at mathematics lessons are obvious immediately after a launch of the program (see figure 1). First, we can see a work surface with a menu of geometric tools (for example Point, Line, Perpendicular Line and so on) and we can show axes of Cartesian or polar coordinates. So, the easiest way of utilization of GeoGebra for education is a solving of geometric problems. We can work with coordinates also during lessons of analytical geometry and count with vectors. GeoGebra also works like graphic calculator so we can use it for a drawing of functions and at higher levels of mathematics we can use tools for calculus. There is no reason to write down more about math because this proceeding is focused on utilization of GeoGebra at physics lessons. But we can get more inspiration for math lessons after obtaining of some experiences and from the internet. GeoGebra is freely available for non-commercial users at the official webpage (GeoGebra – downloads, 2017).

When we talk about possibilities of utilization for education it is necessary to mention that an elementary using of GeoGebra is very intuitive and we don't need any special course to be able to use it. For example, when we want to create some geometric construction only thing what we must do is to click where we want a point, or click on two points to define a line and so on. Moreover, when we put our cursor on some tool GeoGebra shows us a small window with instructions how the tool use. And if we prefer writing of commands we can use the Input Bar (which we can see down at the figure 1) what can be faster than clicking with cursor. List of commands is available at the official webpage (GeoGebra – commands, 2017). Actually, complete GeoGebra manual is available at the official webpage (GeoGebra – manual, 2017).

Another plus of GeoGebra is that this software has millions of users around all world who share lots of already done educational materials for mathematics or physics. We can freely use these materials, or we can download and edit them, or we can find an inspiration in them and create our own. Except of these materials on the internet there are also lots of instructions how to create some applets, or how to use some specific tool. Due to these facts
we can become advanced users by self-teaching and we don’t have to go through any course of GeoGebra.

Fig. 1. GeoGebra work surface with Cartesian coordinates after launching.

Animations and interactive tools of GeoGebra belong to advance using of this software but they are still simple to use. For animations there is a tool Slider which creates some variable which we can change with our cursor or just automatically with defined speed in time. Then we can create for example point of which coordinates could somehow depended on the variable. Simple example is shown at figure 2 where is a Slider with the variable $t$ and the Point $P$ of which $x$-coordinate is $t$ and $y$-coordinate is $2t$ (this is shown in Definition bar at the window with properties of $P$). In left-down corner of the figure 2 is shown Play button which starts the animation.

Fig. 2. Example of a Slider with the variable $t$ and the Point $P$ of which coordinates depends on the variable $t$.

As we can see at figure 2 the Point $P$ can show its trace which means that it leaves coloured points on the working surface when it changes its position with changes of the variable $t$. At the figure 3 is shown trace of the Point with coordinates $t$ and $-t^2$. On the picture we can also see a suggestion of a derivation from the density of the track points. Track points are drawn after same time intervals so a long distance between track points means larger velocity of the moving Point $P$ than a shorter distance between track points.
Another interesting interactive tool is for example a Check Box which works with truth values (Boolean values actually) and we can input conditions of an object display depended on truth values of some Check Box (or on a value of some variable or on the existence of some intersection point and so on). Buttons and Input Boxes are more advanced interactive tools and they require more experiences for an appropriate use but on the internet, there are enough materials which show how to use them.

Previous text is only compact list of basic possibilities of GeoGebra and hopefully it shows that this software could be a useful tool for mathematics education. But all the facts mentioned above suggest possibilities of using GeoGebra at physics lessons and for creating of physics applets. Moreover, simple using of this software enables also students to work with it. This proceeding has no ambition to show all possibilities of GeoGebra or to present detailed instructions for designing of particular applets. But in the text below there are presented some ideas for physics applets which could be a starting point for an own creation.

2 Simple applets for physics education
Basic information about GeoGebra could suggest that we can use this software for physics education. Geometry has immediate utilization in a geometrical optics, Kepler’s laws, characterization of physical quantities with vectors etc. Calculus is necessary for accurate
definitions of some physical quantities and for solving many physics problems and Statistics with probability has obvious utilization in statistical physics and quantum mechanics. Some suggestions how to use GeoGebra during physics lessons at secondary school are mentioned below.

2.1 Graphs of Motion
Maybe the easiest way how to use GeoGebra in physics lessons is a drawing of functions. Some physical exercises are devised for solving with graphs. Students can study graphs of motion and search for coordinates of some intersection points. This could be only way how to solve some problems if they do not know how to deal with equations. Moreover, if students do not know calculus then a drawing of functions helps them to solve problems devised for example on seeking of extremes. Typical secondary school problem is a projectile motion where students seek a maximum range of projectile which is depended on the elevation angle. We can find that the maximum range\(^1\) is for elevation angle 45° by trigonometric identities or by calculus. And if we don’t know calculus and we don’t know right identity then a drawing of the function is maybe only way how to find the solution.

2.2 Geometrical Optics
Students are usually learning at secondary school about paths of light rays and they construct images of objects which are results of reflection on various reflectors. Sometimes they have misconception that a concave spherical mirror works like a concave parabolic mirror (that spherical mirror has a focus) and a simple applet can show the difference between these two kinds of mirrors. At the figure 4 is an example of the light ray path with reflection on a concave spherical mirror. For comparison at the figure 5 is the light ray path with reflection on a concave parabolic mirror. The applet which shows behaviour of a concave spherical mirror is freely available for using or downloading at author’s GeoGebra webpage (Kolar, 2017). When we move with the light source on the applet we can see a motion of the intersection point of the light ray with the optical axis (this point is in the applet called “focus”). Such basic applet is the matter of minutes and it is up to us how much time we invest to work out the applet in detail.

\[\text{Fig. 4. The path of the light beam with reflections on the concave spherical mirror.}\]

\(^1\)We require homogeneous gravitational field and no drag.
2.3 Harmonic Oscillator

When we have more time for designing of an applet we can create relatively sophisticated physical model. An example can be a harmonic oscillator (Kolar, 2017) where we can create a model of spring in GeoGebra. A motion of such model we can compare with a uniform circular motion and we can draw a graph of oscillating point coordinate depended on a time (see figure 6). We can also drawn graph compare with a real experiment.

2.4 Wave

Possibly the most sophisticated applet created with basic GeoGebra tools is a model of wave propagation (Kolar, 2017). With basic tools it is much more complicated than with numerical methods and scripting but when it is done we can consider it a work of art. For example, we can deal with the wave propagation by the Condition to Show Object tool. We let the static points disappear at the right moment and simultaneously let the oscillating points show. Picture of such applet is shown at the figure 7.
2.5 Projectile Motion

An applet which simulates a motion of projectile in a homogeneous gravitational field with no drag is given as an example of applet with more sophisticated GeoGebra tools (Kolar, 2017). As we can see at the figure 8 there are used Buttons and Check Boxes. We can let to execute lots of commands by one click on a particular Button when we in the properties of the Button in the window Scripting in the tab On Click input commands which we want. For example, we can create a button Reset which after a click set a specific position of the projectile, set a specific initial velocity and an intensity of gravitational field, set a specific elevation angel and erase all recorded trajectories of the projectile. One Check Box relates to a quadratic function which fits a trajectory of the projectile and second Check Box shows or hide a point which track its position.

3 Conclusion

GeoGebra is a freely available software with many sophisticated tools which allow us to create lots of educational materials for mathematics and physics lessons. Basic tools are intuitive to use and requires no specific experiences with GeoGebra, so no one must go through any course of GeoGebra to be able to use it. Lots of things we can discover by self-teaching and on the internet, there are lots of already done materials and instructions where we can find inspiration. In the text above are shown some examples how to use GeoGebra in physics and all mentioned applets are open-source and we can freely download them. The applets show only basic possibilities of GeoGebra – for example
coordinates of points depended on a time, recording of a track, geometrical solving of physical problems and so on. But this proceeding should be only informational and should show the starting point of the way how to use GeoGebra during physics lessons at secondary schools.

References

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