Spot the Physics

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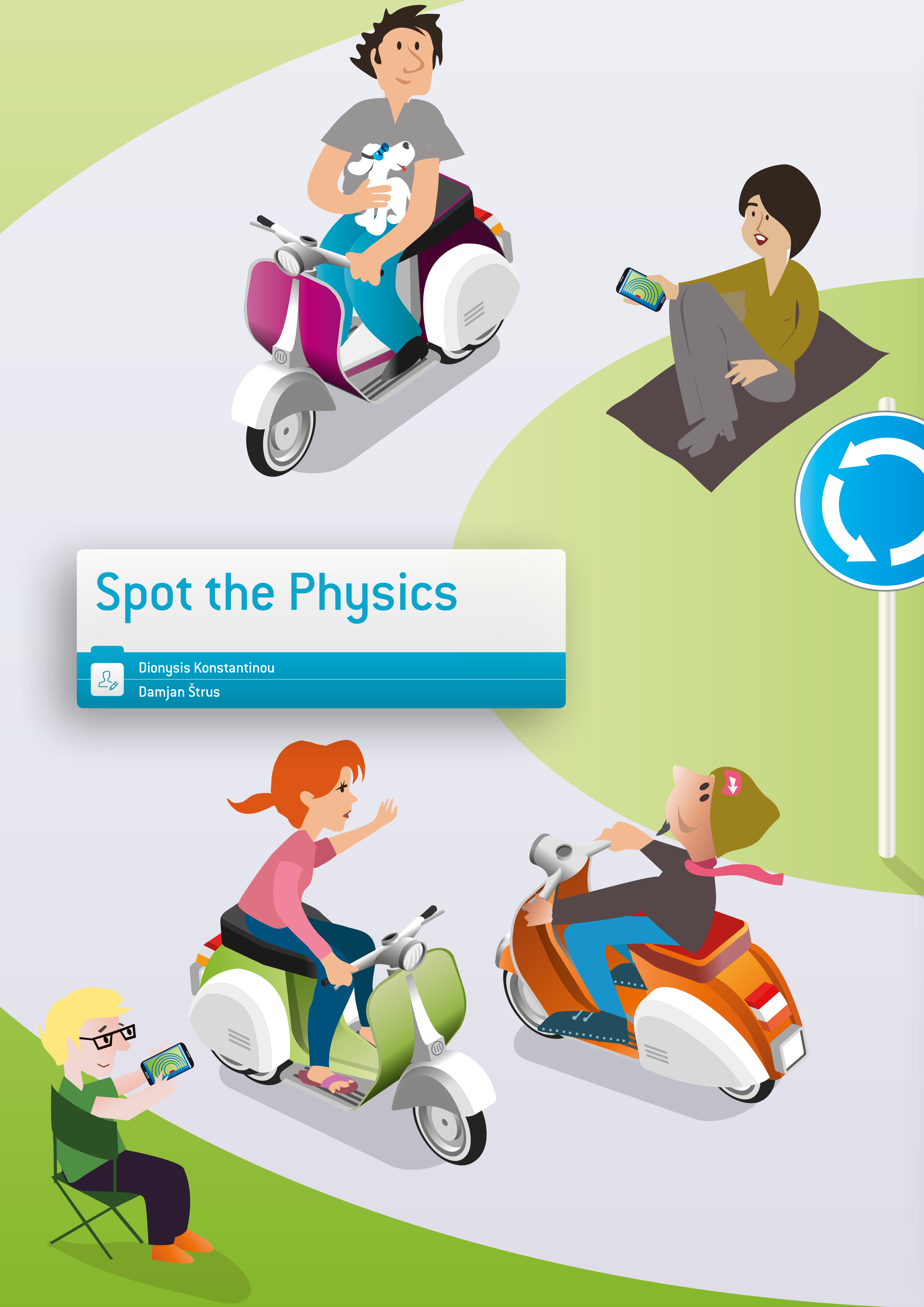


1 | Summary

In this unit we present a few examples of how students can use smartphones to conduct physical video analysis of different physical events (movements). It is possible to use the smartphone for the whole analysis, but students can also combine the use of their smartphones with a freeware program named Tracker (or something similar).

- **Keywords:** Tracker, physics, video analysis
- **Discipline:** physics (linear and curved motions, oscillations, collisions)
- **Age level of students:** 15-19 years
- **Android apps:** VidAnalysis (will be released in December 2014)
- **iOS apps:** Adidas Snapshot, Video Physics from Vernier
- **Further computer software:** Tracker

2 | Conceptual introduction

The students prepare an experiment or observe an event (see examples below), record a video and import the video into an application that can make a physical analysis of the selected phenomenon (a smartphone application or Tracker).

The aim is to have the students:

- Compare their theoretical knowledge with their own data, which they have obtained from a real-time experiment or event, and/or
- Derive a physical law.

This activity is very suitable for learning outside the classroom (on an excursion, a trip, at summer camp etc.) in situations where the students have only their smartphones with them. They can learn even while they are riding along the highway on a bus instead of just playing games.

3 | What the students do

The students first have to decide whether they want to record a new video, choose an existing video from their smartphones or borrow a free video from Sample Videos (e-Book, samples from Tracker or a similar program) and import it into their smartphones. Below we offer a few examples of physical experiments or events that students can record with their smartphones:

- An inclined throw of a basketball
- A horizontal throw of a basketball
- A free fall and vertical throw of a basketball
- Acceleration of a cyclist on a horizontal surface (using different gears)
- Downhill free acceleration of a cyclist (or a tennis ball)
- Harmonic and damped oscillations of a spring
- Circulation of the tip of the second hand of a watch
- Circulation of a car on a roundabout
- Elastic and inelastic collisions on the air slide

You can find some examples of videos recorded by our students during their project work in school in the iBook.

When the students are recording movements, they must pay attention to several very important factors. We will explain our tips using the example of an inclined throw of a basketball.

FIG.1 **Screenshot from the video of an inclined throw of a basketball**

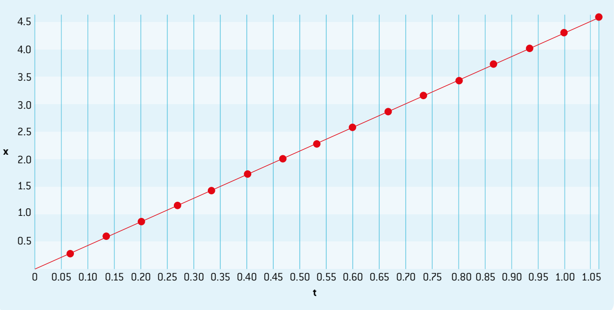
- During the recording, the students must hold their smartphones steady. They should not move the camera, because the analysis assumes the camera is in a fixed position. They also have to keep the plane of motion parallel to the plane of the camera lens.
- The object in motion should remain approximately in a plane perpendicular to the viewing direction.
- The video must be taken from the smallest possible distance, but it is necessary to record the entire motion. In our example, this means that the basketball should not disappear from the video at the top of the parabola.
- The students need to measure a real dimension of the moving object in order to scale the video. In our example we measured the diameter of the basketball.
- During the recording process, the students should consider the lighting conditions in order to have as clear a video as possible.

After recording the video and importing it into the application, the students should make a physical analysis of the selected phenomenon. To conduct the video analysis, the students can use one of the apps mentioned above, i.e. Tracker or a similar program. You can find complete instructions for using Tracker in the iStage 1 brochure, which is available at www.science-on-stage.de/iStage1-download.

The main part of the analysis is to obtain graphs such as x(t), y(t), y(x), $v_x(t)$, $v_y(t)$, v(t), $E_{kin}(t)$, $E_{pot}(y)$ etc. The students will use these graphs to derive further experimental data, which they can compare with a theory and use for further calculations.

Below are a few results (graphs) and tips concerning the selected example (an inclined throw of a basketball).

FIG.2 Graph x(t) of the inclined throw

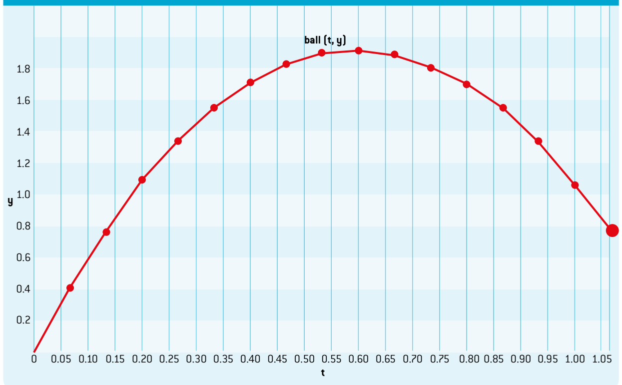


From **FIG. 2** you can see that v_x is constant; on the x-axis the unit is metres, on the t-axis the unit is seconds. Below this graph is the equation of the fit ($x = a \cdot t + b$), and the program gives us the value for the velocity of the ball in the horizontal direction (parameter a): $v_x = 4.3$ m/s.

Further tasks for students:

- Convert this value into km/h and mph.
- Choose two points from the line, calculate the slope and compare it with the v_x value.

FIG.3 Graph y(t) of the inclined throw



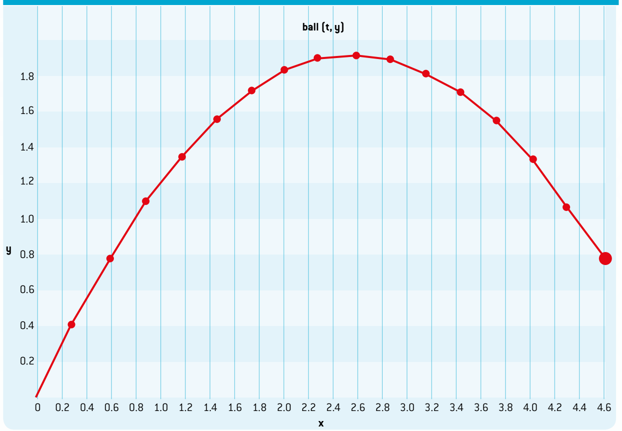
On the y-axis the unit is metres, on the t-axis the unit is seconds. The slope of the tangent of the parabola shows the velocity of our ball. The sign of the slope changes—that is because the direction of the ball in the vertical direction changes. The ball reaches the highest point at the vertex, where the slope of the tangent is zero.

Further tasks for students:

1. Write a mathematical equation for the parabola. Write a physical equation for the path of the ball in an inclined throw. Think about what information you can get from the parameters of the parabola. **FIG. 3** shows the actual path of the ball. The curve is called a parabola, and the smartphone application or Tracker allows you to fit the path and get the parabola's parameters.

2. The students should plot four additional graphs based on Graphs 1 and 2 before they look at the solution:

FIG.4 Graph y(x) of the inclined throw



Graphs $v_x(t)$ and $v_y(t)$
Graphs $a_x(t)$ and $a_y(t)$

FIG.5 Graph showing the change in the velocity in the vertical dimension during the throw

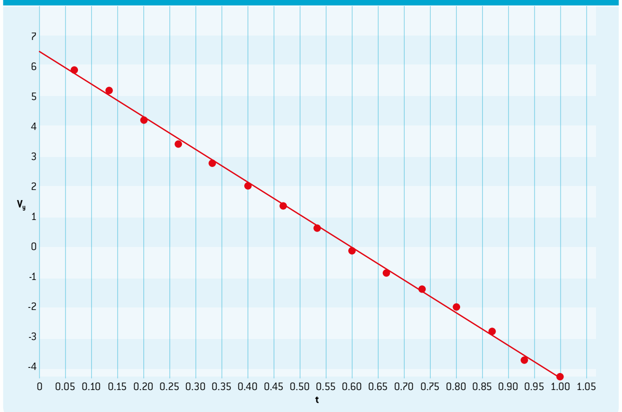


FIG. 5 shows the change in the velocity in the vertical dimension during the throw; on the v_y-axis the unit is metres per second, on the t-axis the unit is seconds.

3. Choose two points from the line and calculate the slope of the line. Do not forget to calculate with units.

Below this graph is the fit equation ($v_y=a \cdot t+b$). Compare the calculated slope with the parameter a. You will get the acceleration of this motion. In this case $a = -10.7\ m/s^2$ (it should be $-g$).

Read off the intercept of the line on the vertical axis (v_y). You will get the initial velocity of the ball in the vertical direction (parameter $b = v_{y0} = 6.4\ m/s$).

Use the fit equation for calculating the time the ball takes to rise $v_y=a \cdot t+b$. In this case $t = 0.60\ s$.

Using the previous data, calculate the highest point that the ball reaches during this inclined throw. In this case, it is $h_{max} = 1.9\ m$. You can also check your calculation in **FIG. 3**.

Think about what information you will get if you calculate the area between the line of this graph and the t-axis. Then calculate the size of this area (do not forget the units).

And finally, a few words about VidAnalysis, a mobile application that runs on the Android operating system and was developed by Richard Sadek in 2014 (release in December 2014). The use of this app at an early stage enables the students to learn about the basics of the physical analysis of dynamic phenomena. The operation of the app is quite similar to the previously described tools. At the beginning it is necessary to record a physical phenomenon, import the video into the app and determine the typical length of the phenomenon in the video. The main challenge, once again, is to determine the position of a moving body as accurately as possible. This is a major problem, because it is very difficult to tap precisely with your finger on the moving body on the smartphone's screen. Once this is done, the application immediately presents a graphical analysis of x(t), y(t) and y(x).

4 | Cooperation option

We can organise cooperation between different schools. The students at the first school prepare an experiment, record a video and send it to the second school's students, who analyse it in Tracker and write a report (and vice versa). During the cooperation they can meet through Skype, Viber or any other tool that is appropriate for a video conference and talk about their experiences.

5 | Conclusion

The students can test a physical theory with the help of their own experiments and real-life events. They use their own smartphones as measuring devices, and to conduct the analysis they once again use their smartphones or computers and just click on the mouse—both devices are students' favourite tools/toys nowadays. If the results of their experiment fit the theory, they receive confirmation; if the results do not fit, they can think about the reasons for that (it may be air resistance, or they may have to think about doing the same experiment under different conditions).

By selecting and analysing an appropriate experiment, the students can potentially formulate a physical law.

6 | Personal experience

Students learn or review how to record useful videos, learn to use video analysis tools and think about the reasons why they may end up with differences between theory and practice.

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