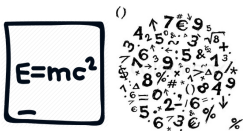


SPEEDING

ACTIVITY 1

SUBJECT



Physics Math

OBJECTIVES

- Understand the concept of "reaction", "braking and stopping" distance.
- Measure the stopping distance on different speeds.



OUTDOOR ACTIVITY

MATERIAL

- ✓ "Vernier Video Physics" app (for iOS)
- "Vision Motion" app (for Android)
- ✓ YouTube Videos:
 - "Video Physics quick start guide"
https://youtu.be/6w2UPngh_Bs
 - "Video Physics export to excel"
<https://youtu.be/ITekJDt7kMw>

This experiment allows the development of the stopping distance concept by self-experience. This activity is an outdoor activity, which can be performed in a schoolyard or on a sports field. The children determine their own braking distance by running or cycling and stopping. This activity is filmed with a mobile phone, the video is then analysed in class with the app "Video Physics".

When trying to stop on an optical or acoustic signal while driving, you need time to react and during this time you are still moving forward - the so called "reaction distance". Students notice that the speed and the condition of the ground have a great influence on the length of the "braking distance". The addition of the "reaction distance" and the "braking distance" results in the "stopping distance". The children realize the fact that the stopping distance of a car is much longer than their stopping distance of a bicycle.



Fig. 1: „Video Physics“ experiment

ACTIVITY OUTLINE

In order to analyse this experiment in a physics lesson the described movement is filmed with a mobile phone with the app "Vernier Video Physics" installed:

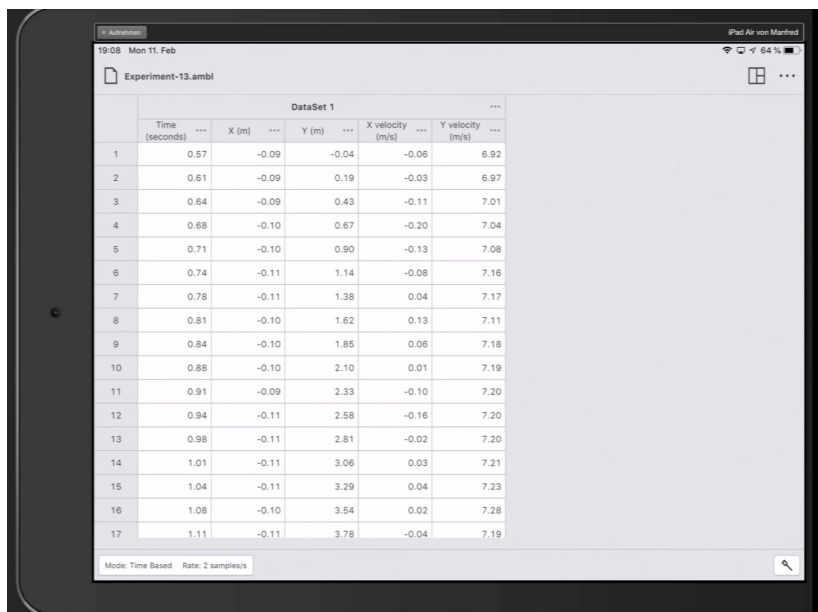
<https://itunes.apple.com/us/app/vernier-video-physics/id389784247>

"Video Physics" will display the path of the moving object and provide graphs of y vs. x as well as the x and y position and velocity as a function of time. The app offers an automatic tracking of an object, which works best with objects that are very different than their background. During recording of the video the mobile must not moved and the object in motion should remain approximately in a plane perpendicular to the viewing direction. Using the app at first you have to import the recorded video and to set the scale of the video using an object of known size. You can choose the position and the origin of coordinate system so that it fits best to the recorded movement.

Discuss the graphs of the x and y position and velocity as a function of time and find out information about the reaction time and the braking distance of the biker.

You can export the recorded data as csv format and import in MS Excel. As first step you have to export the data in the app Video Physics as „Graphical Analysis File“. This file you open with the app „Vernier Graphical Analysis 4“, which displays the graphics as well as the time, x, y and velocity data.

Now you can export this data as .csv file and send per eMail to a desktop PC. With the desktop PC and MS Excel you can import the .csv file and analyse the data with the features of Excel. For example use the formula $a = \frac{v(t_2) - v(t_1)}{t_2 - t_1}$ to calculate the deceleration during different intervals of the braking process of the bicycle.



The screenshot shows a data table with the following columns: Time (seconds), X (m), Y (m), X velocity (m/s), and Y velocity (m/s). The data points are as follows:

Time (seconds)	X (m)	Y (m)	X velocity (m/s)	Y velocity (m/s)
0.57	-0.09	-0.04	-0.06	6.92
0.61	-0.09	0.19	-0.03	6.97
0.64	-0.09	0.43	-0.11	7.01
0.68	-0.10	0.67	-0.20	7.04
0.71	-0.10	0.90	-0.13	7.08
0.74	-0.11	1.14	-0.08	7.16
0.78	-0.11	1.38	0.04	7.17
0.81	-0.10	1.62	0.13	7.11
0.84	-0.10	1.85	0.06	7.18
0.88	-0.10	2.10	0.01	7.19
0.91	-0.09	2.33	-0.10	7.20
0.94	-0.11	2.58	-0.16	7.20
0.98	-0.11	2.81	-0.02	7.20
1.01	-0.11	3.06	0.03	7.21
1.04	-0.11	3.29	0.04	7.23
1.08	-0.10	3.54	0.02	7.28
1.11	-0.11	3.78	-0.04	7.19

Fig. 2: Data from "Video Physics" displayed in 'Graphical Analysis

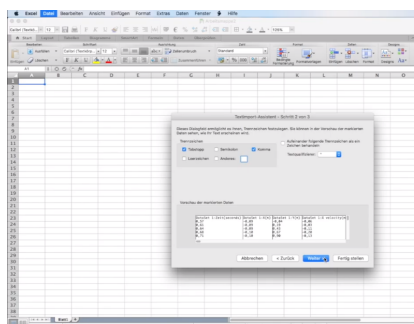
QUICK GUIDES TO THE "VERNIER VIDEO PHYSICS" APP

The following youtube video gives a quick start guide for the app! In the video the front tire of the car was tracked automatically. For the activity described above it is suggested to track the front wheel of the bicycle.



https://youtu.be/6w2UPngh_Bs

The following youtube video demonstrates how to export the recorded data from „Video Physics“ to MS Excel.



<https://youtu.be/ITEkJDt7kMw>

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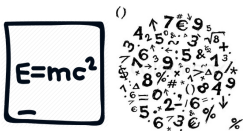


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SPEEDING

ACTIVITY 2

SUBJECT



Physics Math

OBJECTIVES

- Understand the concept "stopping distance".
- Measure the stopping distance on different speeds.



IN CLASS ACTIVITY

MATERIAL

- ✓ "Vernier Video Physics" app (for iOS)
- ✓ "Vision Motion" app (for Android)
- ✓ Videos:
 - "Braking distance with video physics"
<https://www.youtube.com/watch?v=4p6PBdoD4g0&feature=youtu.be>

ACTIVITY OUTLINE

Watch the video about the braking distance of a car: an emergency stop of a car was filmed with a tablet and analysed with the app "Vernier Video Physics". The App "Video Physics" brings automated object tracking and video analysis to iPhone and iPad. You can capture a video of an object in motion, then you tap to track an object automatically. "Video Physics" creates trajectory, position, and velocity graphs for the object. In the video "Video Physics" was used to track the front tire of the car.

Discuss the following tasks with the graphics of figure 2 and figure 3, which were created with "Video Physics"!



Fig. 1: "Braking distance with video physics"

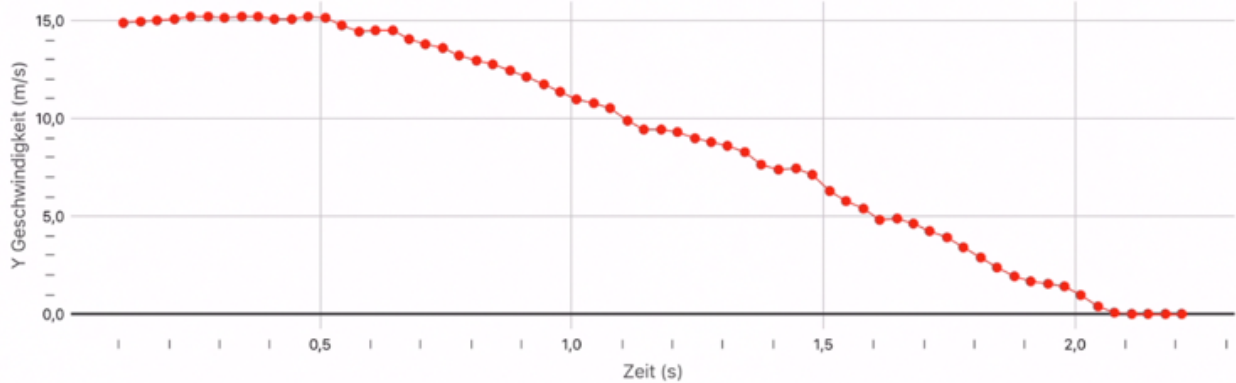


Fig. 2: speed-time diagram created with Video Physics

Task 1: Describe the sections of the movement of the car with the help of the speed-time diagram of figure 2.

Solution: Figure 2 shows a horizontal straight line in the speed-time diagram in the first section - this represents a movement of the car at constant speed; In the second section, the movement is described by a straight line with a negative slope - this represents a uniformly delayed movement.

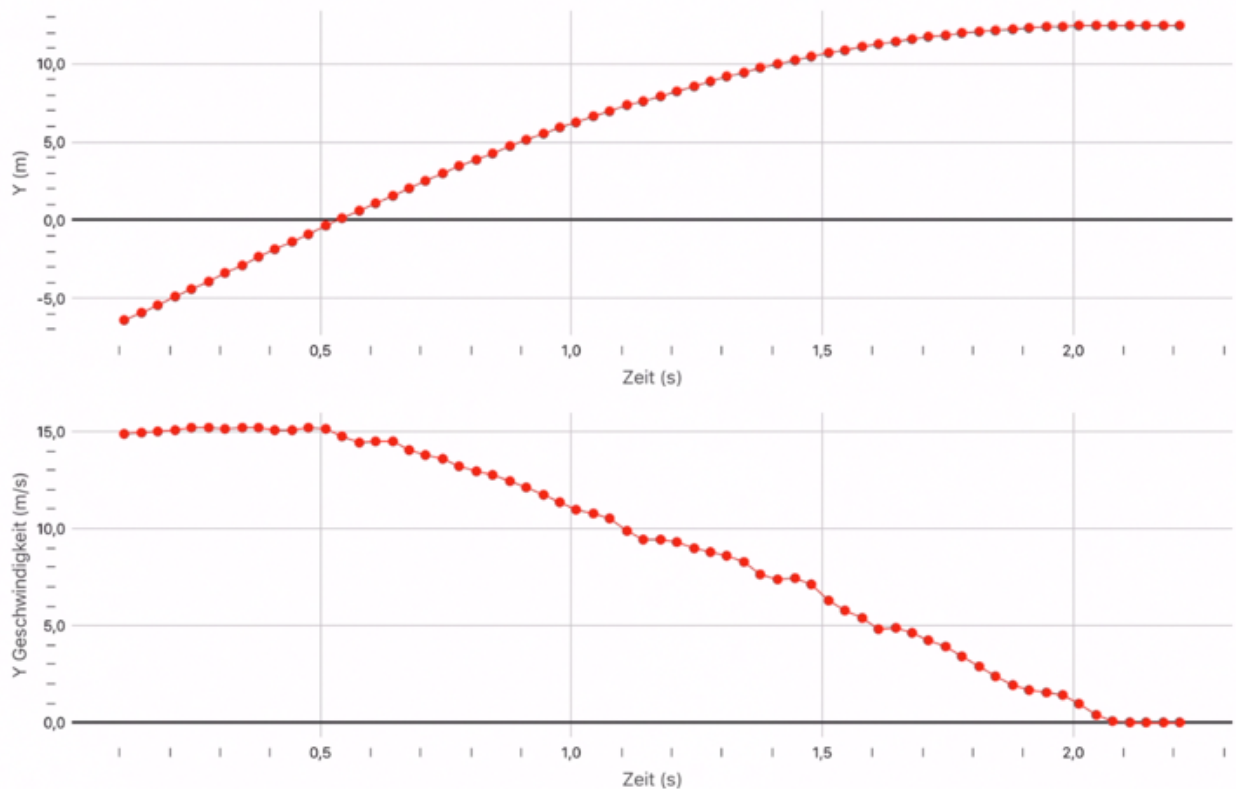


Fig. 3: speed-time diagram and velocity-time diagram created with Video Physics

Task 2: The instantaneous velocity of a uniformly delayed movement is given by the formula $v(t) = v_0 - a \cdot t$. Interpret the formula using figure 3 and use this formula and the data you read in figure 4 to determine the deceleration a of the braking process.

Solution: The formula represents the line with the negative slope - the slope is given by $-a$. From the graphic you find: $v(0,5) = 15$ and $v(1,5) = 5,4$ you get with $a = \frac{\Delta v}{\Delta t} = \frac{v(1,5) - v(0,5)}{1,5 - 0,5} = -9,6$, which means $a = -9,6 \text{ m/s}^2$

Task 3: Use the graphs in figure 3 to estimate the length of the braking distance. Explain how to know when the braking process started.

Solution: The length of the braking distance can be read in the distance-time diagram: it is the distance traveled from the beginning of braking at 0,5 seconds to standstill at 2,05 seconds; that is about 12 m.

Task 4: The braking distance is calculated using the formula $s = \frac{v^2}{2 \cdot a}$. Use this formula and the results from above to calculate the braking distance. Compare the result with what you determined in figure 3.

Solution: With the formula for the braking distance s and the results from above one calculates: $s = 15^2 / (2 \cdot 9,6) = 11,7 \text{ m}$; this agrees very well with the value of 12m found in figure 3.

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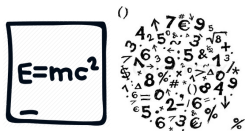


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SPEEDING

ACTIVITY 3

SUBJECT



Physics Math

OBJECTIVES

- Understand the concept "stopping", "reaction" or "thinking" and "braking" distance.
- Measure the stopping distance on different speeds.



INCLASS ACTIVITY

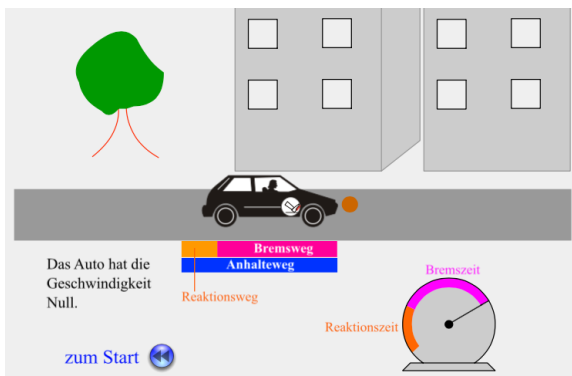


Fig. 1: Screenshot from <https://www.leifiphysik.de> stopping distance animation

MATERIAL

- ✓ Stopping distance animation (in German): <https://www.leifiphysik.de/mechanik/lineare-bewegung-gleichungen/ausblick/anhalteweg>
- ✓ Stopping distance calculator (in English): http://www.roadsafetyweek.org.uk/stopping-dist-calc/story_html5.html

ACTIVITY OUTLINE

Use the animation "stopping distance" and discuss in the classroom the differences between "stopping distance", "reaction or thinking distance" and "braking distance".

Task 1: The reaction distance of a car is the distance the car travels from detecting the danger to pressing the brake. Discuss the factors which have an influence on the length of the reaction distance!

Solution: The reaction distance depends on the reaction time of the driver and the speed of the vehicle. Detecting the danger usually takes about 0,1 s (a moment). The time of the reaction of the driver is 0,8 s. The brake response time, also called swell time, is the time it takes the brakes to deploy the maximum braking effect.

In a hydraulic brake system, the time is between 0,1 and 0,2 seconds, in the compressed air brake system between 0.2 and 0.6 seconds. The reaction time depends on the condition of the driver, i.e whether he is concentrating and whether he is under the influence of alcohol or drugs.

Task 2: Tick the correct statements on the topic of braking distance.

1. The braking distance is the distance covered from detection of the danger to the actuation of the brake.
2. The braking distance is the distance covered by the brake application until the vehicle stops.
3. The reaction path depends on the road surface.
4. The braking distance depends on the road conditions.
5. Double speed (with the same road condition) results in twice the braking distance.
6. Double speed (with the same road condition) gives four times the braking distance.

True statements: 2, 4, 6

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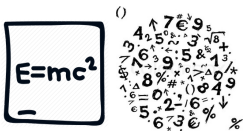


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SPEEDING

ACTIVITY 4

SUBJECT



Physics Math

MATERIAL



Video:

"Understanding Anti-lock Braking System (ABS)"

<https://youtu.be/98DXe3uKwfc>

OBJECTIVES

- Understand the concept of "reaction", "braking" and "stopping" distance.
- Measure the stopping distance on different speeds.



IN CLASS ACTIVITY

Modern cars are equipped with an anti-lock braking system (ABS), a safety anti-skid braking system, which operates by preventing the wheels from locking up during braking, thereby maintaining tractive contact with the road surface.

The following Activity helps students to understand how this system works in terms of physics and engineering.

ACTIVITY OUTLINE

TASK 1:

Watch the video and discuss, how the ABS system improves the safety during an emergency braking.

Solution: In order to obtain the shortest possible braking distance, it is necessary to prevent blocking of the tires. Sliding friction would significantly extend the braking distance and the steering ability would also be lost.



Fig. 1: Video "Understanding Anti-lock Braking System (ABS)"

Crucial for the intervention of the auxiliary systems ABS is the slip. The slip results during braking from the relationship between the speed of the rubber against the road and the speed of the vehicle. With a slip of 0 the tire sticks, with a slip of 100% it blocks completely. From the perspective of a braking car, the brakes first try to bring the car to a standstill, but the stiction still tries to turn the tire.

The stronger the brakes work, the stronger the friction between the tire and the road, which slowly increases the slip. The braking behaviour is still stable, as a greater pressure on the brakes continues to cause a greater braking force. However, if the frictional force exceeds its maximum due to over-tightening of the brakes, the frictional force between the tire and the road decreases. The tires block, the braking effect decreases and the braking behaviour becomes unstable. A greater pressure on the brakes only causes a lower braking force. Figure 2 shows the operation of the ABS by adjusting the brake pressure as a function of the wheel speed and the vehicle speed. The wheel speed is controlled so that the slip always dwells in the range just below the friction coefficient maximum, but does not exceed this.

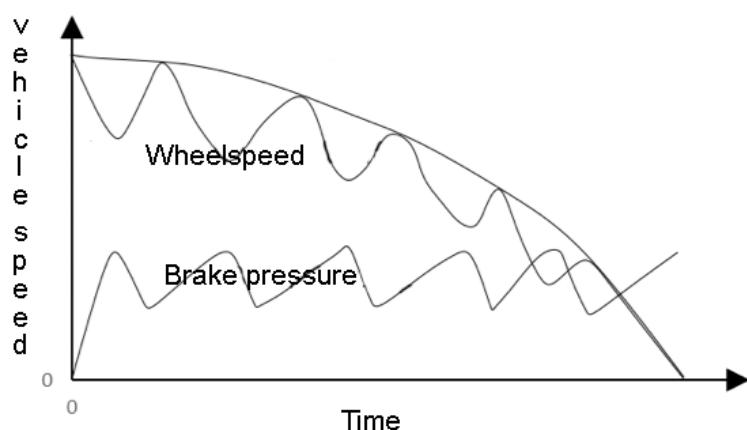


Fig. 2: wheel-speed and brake pressure with ABS

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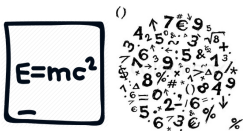
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SPEEDING

ACTIVITY 5

SUBJECT



Physics Math

MATERIAL



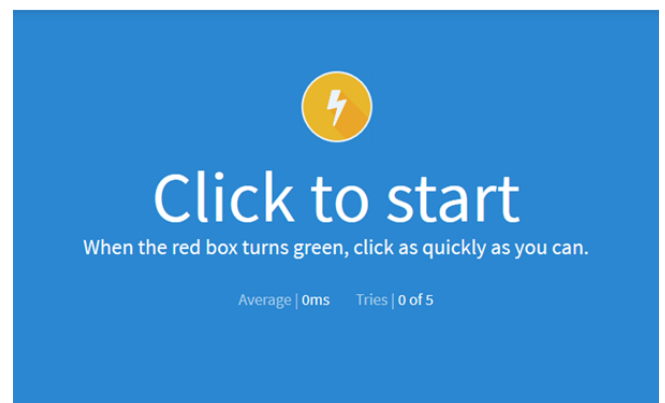
[https://www.humanbenchmark.com/tests/reaactiontime](https://www.humanbenchmark.com/tests/reactiontime)

OBJECTIVES

- Understand the concept "braking distance".
- Measure the stopping distance on different speeds.



IN CLASS ACTIVITY



ACTIVITY 5

ACTIVITY OUTLINE

1. Introduction/Preparation

In this phase, students are asked to think about the relation of speed and distance traveled before braking for various speeds. Before starting any calculation, they are encouraged to freely express their opinions (e.g. how much could this distance be for vehicles at highway traveling at 60 km/hr, 80 km/hr, 100 km/hr). Teacher then introduces the notion of reaction time.

2. Investigation

The students are instructed to fill in a spreadsheet with columns of speed in km/hr (from 10 to 120), speed in m/sec and distance traveled for 200 msec (=0,20 sec) and 250 msec (0,25 sec). A sample xls sheet is show below.

If the lesson If this lesson is conducted in a computer lab then students can be grouped in small teams of 3-4 persons and use one pc per team to try the following reaction time test or similar apps : <https://www.humanbenchmark.com/tests/reactiontime>

They record their results in a spreadsheet. Then they calculate the average value achieved per team. Each team then update the initial spreadsheet with one more column of Distance for the average value of reaction time per team. They update also the initial graph.

3. Presentation/Communication

In this phase students plot in a graph Distance vs Speed for various values of reaction time. Each team presents its results.

DISCUSSION - REFLECTION

Students discuss and reflect on their findings, they compare them with what they thought and expressed spontaneously during the Introduction/Preparation phase. They discuss the implications of their findings in relation to safety distance, speed limits, speeding violations, etc

Speed	Speed	Distance	Distance	Distance
km/hr	m/sec	m	m	m
		in 1 sec	in 200 msec	in 250 msec
10				
20				
30				
40				
50				
60				
70				
80				
90				
100				
110				
120				

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