Potenzielle und kinetische Energie mit SMARTsense

(Item No.: P1004069)

Curricular Relevance

Area of Expertise: Physics
Education Level: Age 16-19
Topic: Mechanics
Subtopic: Energy and momentum
Experiment: Potential and kinetic energy with SMARTsense

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	20 Minutes	10 Minutes	2 Students

Additional Requirements:

- Tablet

Experiment Variations:

- Classic student experiment: Potential and kinetic energy (P1004005)
- Classic student experiment: Potential and kinetic energy with the 2-1 timer (P1004005)

Keywords:

conservation of energy, potential energy, kinetic energy, velocity

Information for teachers

Introduction

Application
Energy is one of the most important physical quantities.
It influences our everyday life in many different ways: We need to absorb energy in the form of food, we need energy in order to drive our cars, our electric appliances convert energy, we heat our houses with energy, etc.
During all of these processes, we convert potential energy into a form of energy that we can use. One example is the conversion of the potential energy of water in a reservoir into the kinetic energy of the water shooting down the pipes until it is finally converted into electric energy by turbines and generators.
During this experiment, potential energy will be converted into kinetic energy of the cart.

Hydroelectric power station in China (picture: Le Grand Portage)

Experiment set-up.

Educational objective

During this experiment, the students will learn about the conversion of potential energy into kinetic energy and study it in detail. They should understand the meaning of the law of conservation of energy.
The student should be able to see that the kinetic energy is proportional to the square of the velocity $E \propto v^2$ and to determine the proportionality factor k based on the measurement values with $k = m/2$.

Tasks

1. The students let a cart roll on the track. The cart is pulled by a weight via a pulley. The weight accelerates the cart up close to the end of the track. A light barrier at the end of the track measures the shading times Δt of the cart. The acceleration distance of the cart is varied.
2. The students calculate the velocity v of the cart based on the shading times Δt and on the width of the shutter plate ($\Delta s = 5\,\mathrm{cm}$).
3. The students calculate the potential energy based on the acceleration distance s (which is equal to the height difference h of the weight) and they plot it into a diagram as a function of the square velocity v^2. The students determine the gradient k of the linear graph.
4. The students determine the dimension of the gradient k ([k]=kg) and compare it to the total mass m. This leads to $k = m/2$ by way of which the formula of kinetic energy $E = \frac{1}{2}mv^2$ is to be made plausible.

Prior knowledge

The students should know the difference between potential and kinetic energy.
Velocity calculations should not be a problem.
The students should be able to determine the gradient of an approximately linear graph.
The students should be familiar with the concept of physical dimension and they should be able to determine it based on the gradient of the graph.

Principle

The measurement cart on the track is accelerated up close to the end of the track (when the weight hits the floor) by a mass that is connected to the cart by way of a thread via a pulley and that produces a force in the gravitational field.
From an energy-based point of view, the final velocity of the cart simply results from the law of conservation of energy.
On the last section of the track, the cart continues its motion at a constant velocity (which is possible due to a slight inclination of the track). This is where the final velocity will be measured.

Note

In order to adjust the correct inclination of the track (for friction compensation), a second light barrier can be used as follows: Push the cart with one hand and measure the shading time of the first light barrier. Reset the measurement value before the cart

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reaches the second light barrier and measure the second shading time. Compare it to the first one.
(This test can also be performed with only one light barrier by relocating it while the cart is in motion.)

Safety instructions

For this experiment, the general notes and instructions concerning safe experimentation in science classes apply.

Versuch: Potenzielle und kinetische Energie mit SMARTsense (Item No.: P1004069)

Introduction

Application and task

Kinetic energy of a rolling cart

Introduction
Up to now, you have been engaged in the description of types of motion.
Now the question is why the cart is actually set into motion and how its motion is connected to energy.

During this experiment, you will convert potential energy into kinetic energy of the cart and perform several measurements during this process.

Maybe you already have an idea about how the experiment should be set up and how you could proceed.

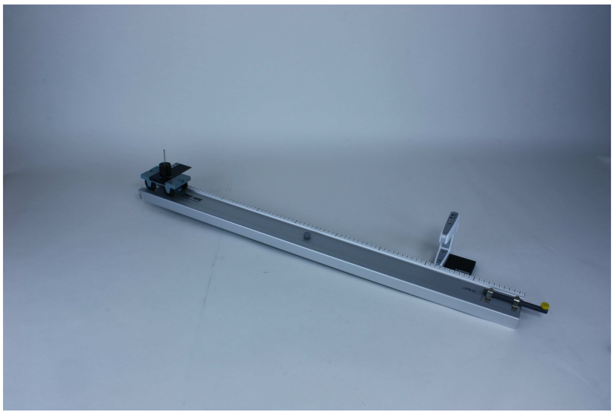
Application
The potential energy of water in a reservoir can be converted into the kinetic energy of the water shooting down the pipes until it is finally converted into electric energy by turbines and generators.

The kinetic energy of wind, for example, is used to generate electricity by way of wind turbines.

Hydroelectric power station in China (picture: Le Grand Portage)

Tasks

1. Release the cart so that it will be accelerated by the weight up close to the end of the track (when the weight hits the floor). On the last section of the track, measure the shading times Δt of a light barrier for various different acceleration distances s.
2. Calculate the velocity of the cart based on the shading times Δt and on the width of the shutter plate of the cart $\Delta s = 5\,\mathrm{cm}$.
3. Calculate the potential energy based on the acceleration distance s (which is equal to the height difference h of the weight) and on the mass m of the weight. Plot it into a diagram as a function of the square velocity v^2. Determine the gradient k of the graph.
4. Determine the dimensions of the gradient k and compare it to the total mass.



Experiment set-up

Material

Position No.	Material	Order No.	Quantity
1	Track, l 900 mm	11606-00	1
2	Meter scale, demo. l=500mm, self adhesive	03005-00	2
3	Cart for measurements and experiments	11060-00	1
4	Shutter plate for cart	11060-10	1
5	Holding pin	03949-00	1
6	Cobra SMARTsense - Photogate, 0 ... ∞ s	12909-00	1
7	Adapter plate for Light barrier compact	11207-22	1
8	Silk thread, l = 200 m	02412-00	1
9	Weight holder, silver bronze, 1 g	02407-00	1
10	Slotted weight, black, 50 g	02206-01	3
11	Slotted weight, black, 10 g	02205-01	4
12	Pulley,movable,dia.40mm,w.hook	03970-00	1
13	Rod for pulley	02263-00	1

Set-up and procedure

Set-up

Connect the pulley to the associated rod (Fig. 1).

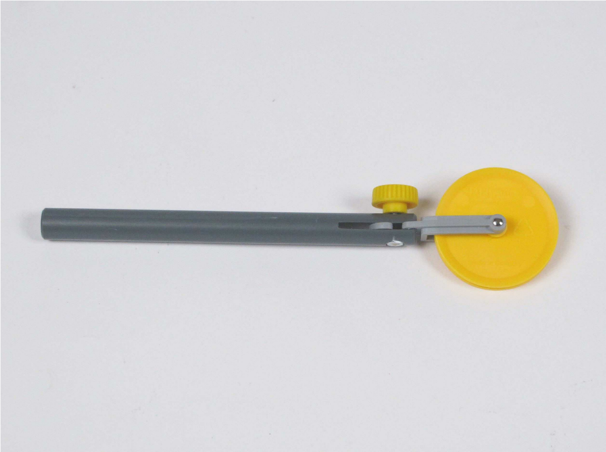


Fig. 1

Push the rod carefully under the holding clamps located at one end of the track. To do so, slacken the holding clamps slightly with your fingers so that the plastic rod will not be damaged by the sharp metal edges. Position the track on the desktop so that the pulley is located at the edge of the table and can be rotated freely (Fig. 2).

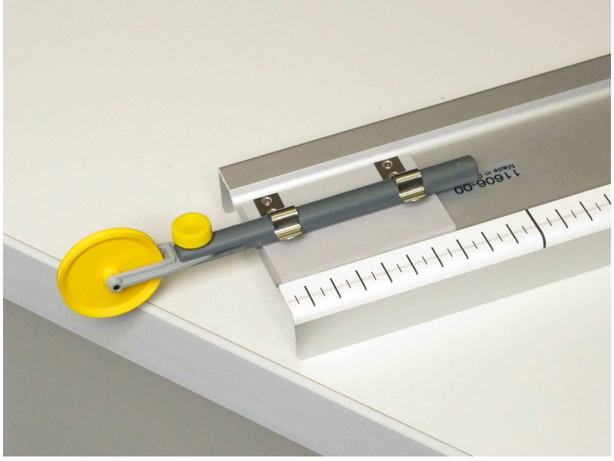


Fig. 2

Fasten the shutter plate to the experiment cart by way of the holding pin and place two slotted weights of 50 g on the cart (Fig. 3).

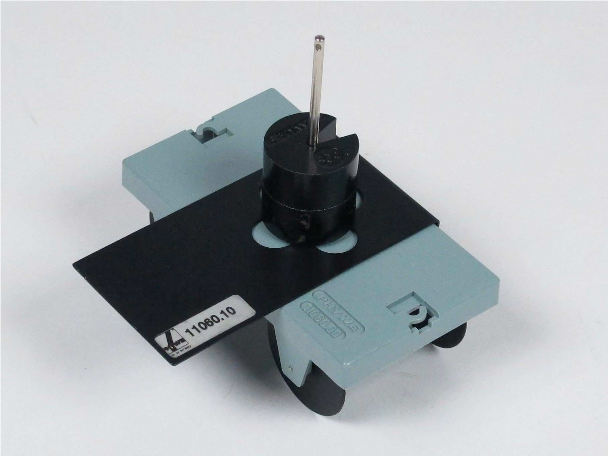


Fig. 3

Incline the track so that the cart continues its motion with the exact same velocity, if possible, when it is pushed by hand into the direction of the pulley. To do so, position the adjusting screw at the other end of the track on slotted weights and adjust the inclination with the screw (Fig. 4).

Fig. 4

Insert a piece of thread through the hole of the holding pin under the cart (Fig. 5), lead it from under the cart on top of the cart and knot it onto the holding pin (Fig. 6).

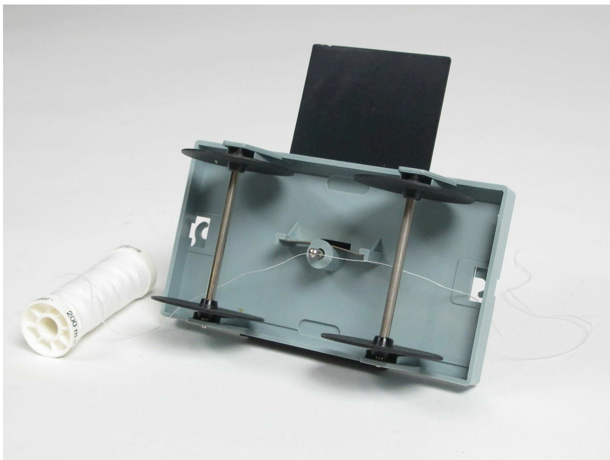


Fig. 5

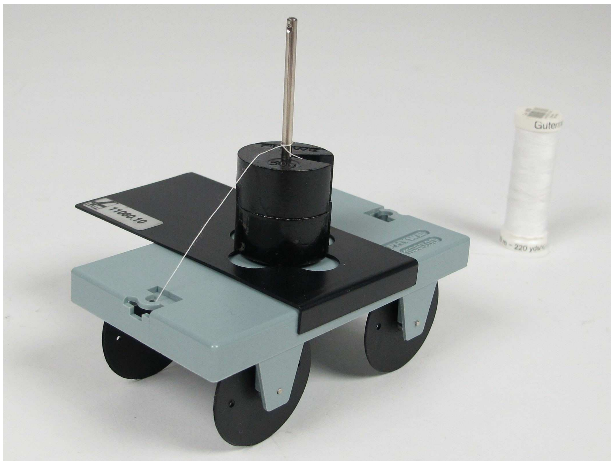


Fig. 6

Knot the other end onto the weight holder (1 g) (Fig. 7). Adjust the length of the thread so that the weight holder will reach the floor when the cart is approximately on the last 15 cm of the track.
(The easiest way to do so is to use a rather long piece of thread and to wind the excess thread around the holding pin and hook on top of the cart. If the thread is slightly too short as a result, you can simply lay a textbook or similar on the floor.)

Fig. 7

Place a slotted weight of 10 g on the weight holder (1 g) so that the total weight pulling the cart is 11 g (Fig. 8).

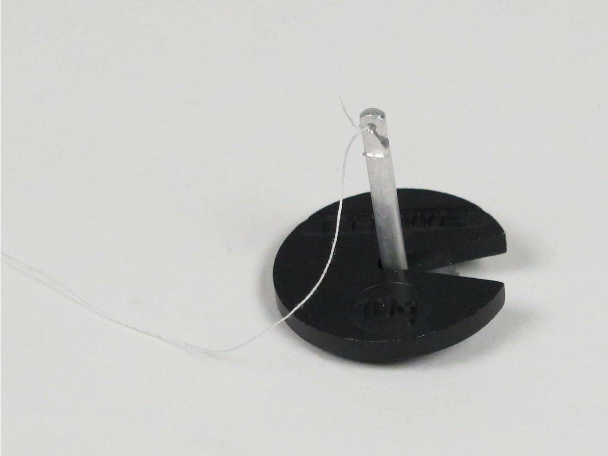


Fig. 8

Lay the thread that connects the cart to the weight holder over the pulley.
Ensure that the thread runs above the axis of the carts and parallel to the track (Fig. 9).

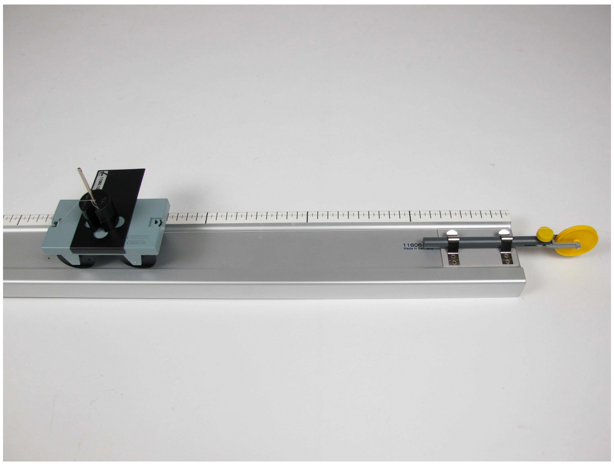


Fig. 9

Connect the adapter plate to the light barrier A so that it can be set up next to the track and that the shutter plate on the cart can pass through the light barrier without touching it (fig. 10).

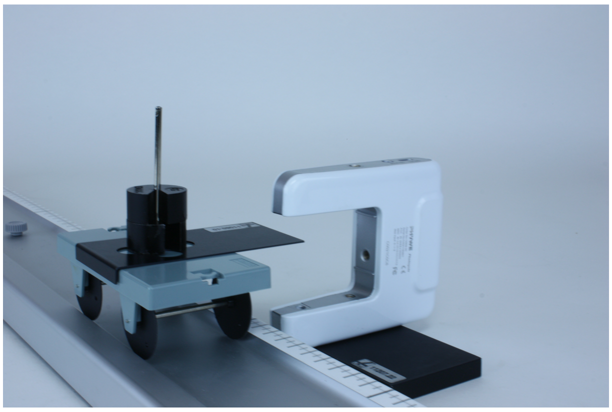


Fig. 10.

Switch on the lightbarrier A. Select then the photogate in measureAPP in the menu "sensor". Pick the option "Shade times" in the menu that opened. (Fig. 11).

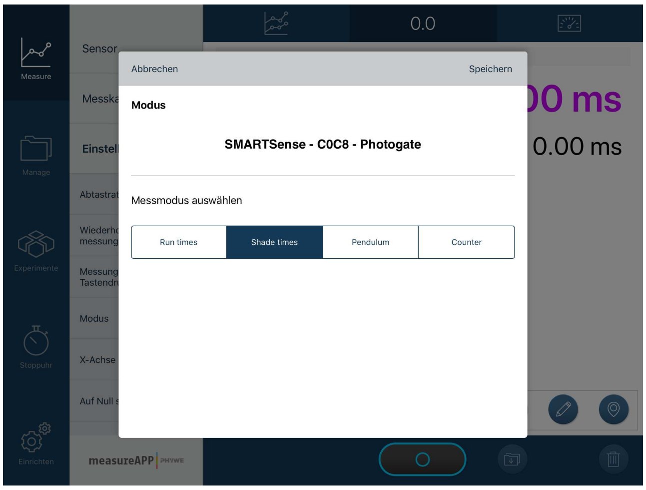


Fig. 11.

With this setting, the light barrier measures the so-called shading time Δt, i.e. the time during which the light beam is interrupted when the shutter plate passes through the light barrier.

Procedure

Make a mental note of the position of the cart when the weight touches the floor and the thread is still taut.
Position the light barrier next to the track so that it will be interrupted as soon as possible by the shutter plate after the weight has reached the floor.

Starting from this position, push the cart $s = 10\,\mathrm{cm}$ up the track. The weight will be lifted by the same distance s. As a result, the distance s equals the height h of the weight above the floor.

Check whether the thread runs over the pulley and whether the pulley can rotate freely.
Change the display to numerical mode 0.0 (fig. 12).
Start the measurement by pressing on .
Release the cart without pushing it and catch it behind the light barrier.

Read the shading time Δt, round it to one millisecond, convert the value into seconds, and enter it into table 1 of the experiment report.

Perform additional measurements during which you increase the distance s, by which you pull the weight up with the cart, in steps of 10 cm up to $s = 60\,\mathrm{cm}$.

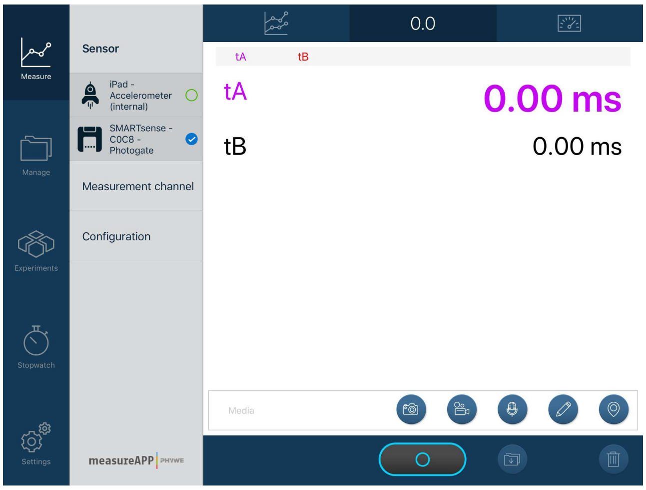


Fig. 12.

Report: Potential and kinetic energy with SMARTsense

Result - Table 1

Enter the shading times Δt into the second column.

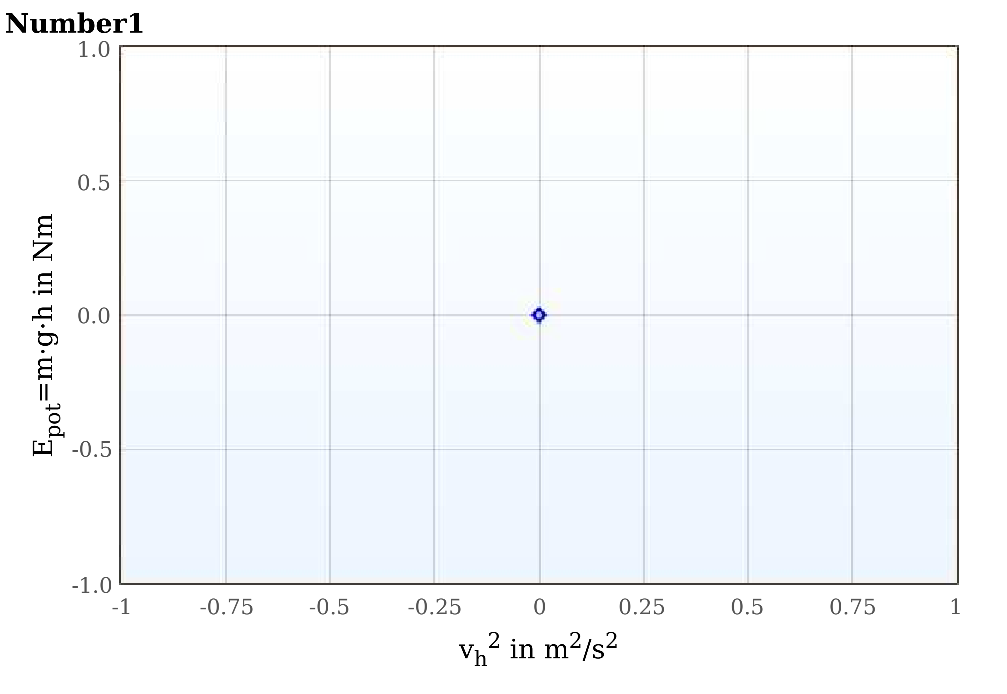
Calculate the final velocities v of the cart based on the shading times Δt and shutter plate width Δs. Enter the values in the second column.

Calculate the potential energy $E_{pot} = m_w \cdot g \cdot h$ (g=9.81 N/kg) and enter the values into the corresponding column.

Calculate the square of the velocities v^2 and enter the values into the table.

See question 6 for the calculation of the last column.

h in m	Δt in s	$v=\Delta s/\Delta t$ in m/s	$E_{pot}=m \cdot g \cdot h$ in Nm	v^2 in m^2/s^2	m_{exp} in kg
			0	0	
0.10	1 ±0.014	1 ±0.037	1 ±0	1 ±0.027	1 ±0.036
0.20	1 ±0.009	1 ±0.046	1 ±0	1 ±0.047	1 ±0.032
0.30	1 ±0.008	1 ±0.061	1 ±0	1 ±0.076	1 ±0.034
0.40	1 ±0.007	1 ±0.068	1 ±0	1 ±0.095	1 ±0.036
0.50	1 ±0.006	1 ±0.074	1 ±0	1 ±0.116	1 ±0.034
0.60	1 ±0.005	1 ±0.072	1 ±0	1 ±0.123	1 ±0.037



Evaluation - Question 1

In the diagram, the potential energy E_{pot} has been plotted as a function of the squared velocity v^2.

What conclusions can be drawn from the graph when taking into consideration that the potential energy has been converted into kinetic energy so that v^2 represents the kinetic energy?

Tick the correct statements.

- [ ] The linearity shows that the kinetic energy Ekin is proportional to the squared velocity Ekin~v2.
- [ ] Since the graph passes through the origin, the cart has no kinetic energy when it is not in motion.

Evaluation - Question 2

Determine the value of the total accelerated mass mtotal = mc + mw (mc: cart mass; mw: mass of the tractive weight).
(The empty cart has a mass of 42 g, the holding pin has a mass of 7 g, and the shutter plate has a mass of 10 g.)
Enter the value (in grams) into the window.

Evaluation - Question 3

Determine the gradient k of the graph in the diagram (Epot against v2) and enter the value into the window.

Evaluation - Question 4

What is the unit of the gradient *k*?

- [ ] [k] = kg
- [ ] [k] = kg/m4
- [ ] [k] = m/s
- [ ] [k] = Nm
- [ ] [k] = s
- [ ] [k] = 1

Evaluation - Question 5

Compare the value of the gradient to the total accelerated mass (see task 2).

The accelerated mass...

- [ ] ... is approximately identical to the value of the gradient.
- [ ] ... is approximately twice the value of the gradient.
- [ ] ... is approximately half the value of the gradient.
- [ ] ... is not in any obvious relation to the value of the gradient.

Evaluation - Question 6

Assume that $E_{kin}=1/2 \cdot m \cdot v^2$ applies to the kinetic energy and that it is equal to the potential energy $E_{pot} = m \cdot g \cdot h$.

In this case, the measurement data of the experiment can be used to determine the values of the accelerated mass m_{exp} by solving the equation $1/2 \cdot m_{exp} \cdot v^2 = E_{pot}$ for m_{exp}.

Calculate this mass based on the fourth and fifth column of the table and enter the values into the table.

Is it possible to confirm the assumed law $E_{kin}=1/2 \cdot m \cdot v^2$ based on the experiment? Justify your answer.

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Evaluation - Question 7

In order to compensate for friction, the track has been inclined slightly. This means the potential energy of the cart has been used to overcome friction.

Think about what would happen if the friction of the cart was velocity-dependent. Are there other influencing factors apart from rolling friction?

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