Conversion of mechanical energy into internal energy with SMARTsense (Item No.: P1044469)

Curricular Relevance

Area of Expertise: Physics

Education Level: Age 14-16

Topic: Energy

Subtopic: Energy: forms, transformation and conservation

Experiment: Conversion of mechanical energy into internal energy with SMARTsense

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Very difficult	10 Minutes	40 Minutes	2 Students

Additional Requirements:

- tablet PC
- measureApp
- tape

Experiment Variations:

Keywords:

energy conversion, potential energy, internal energy

Information for teachers

In this experiment, the potential energy of pellets is first converted to kinetic energy and then to intrinsic energy when they fall in a tube (Whiting tube).

Notes on set-up and procedure:

1. Care must be taken that both stoppers are firmly attached. During turning, it is best to only handhold the stoppers at the two ends.
2. The tube must be turned 200 times, otherwise the temperature differences would be too small. With many more turnings, the duration of the experiment is too long and larger losses result.
3. The measuring tape is inserted down to the pellets when the distance of fall is measured. The pellets should not be pushed to the side when doing this.
4. The mass of the pellets can be subsequently weighed - the temperature increase and the efficiency are, however, independent of the mass. It gets cancelled out in both cases.

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Introduction

When you ride your bike at night, you will need light. A lot of bikes have dynamos for that reason. A dynamo converts the energy of the motion into electrical energy. You can find many energy converters in everyday life. The motor from a car for example converts chemical energy into electrical energy which then again is converted into kinetical energy so that the car moves. Within this exerperiment you will investigate, if other forms of energy conversion are also possible by looking at the example of the conversion from mechanical energy into internal energy.

Task

Can potential energy be converted to heat?

Let the pellets drop the same distance numerous times and measure how quickly they warm up.

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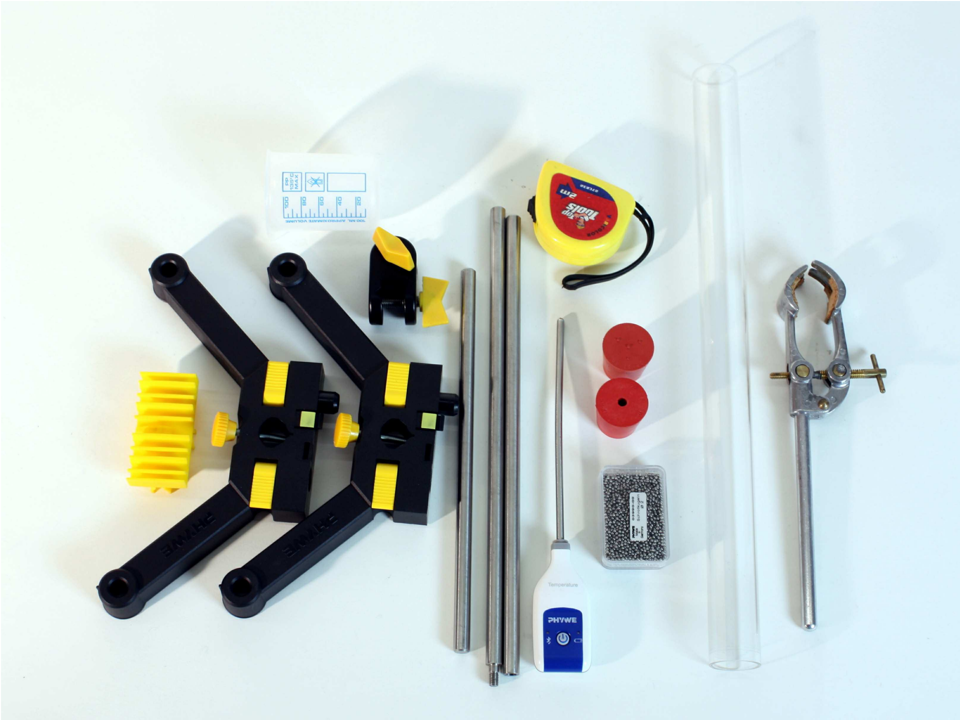
Material



Position No.	Material	Order No.	Quantity
1	Cobra SMARTsense - Temperature, - 40 ... 120 °C	12903-00	1
2	Support base, variable	02001-00	1
3	Support rod, stainless steel, l = 250 mm, d = 10 mm	02031-00	1
4	Support rod, l = 600 mm, d = 10 mm, split in 2 rods with screw threads	02035-00	1
5	Boss head	02043-00	1
6	Glass tube holder with tape measure clamp	05961-00	1
7	Universal clamp	37715-00	1
8	Tube, plastic, d. 30mm, l. 500mm	04446-00	1
9	Rubber stopper 26/32 , without hole	39258-00	1
10	Rubber stopper 26/32, 1 hole 6 mm	39258-06	1
11	Steel pellets, d = 2 mm, 120 g	03990-00	1
12	Beaker, low form, plastic, 100 ml	36011-01	1
13	Measuring tape, l = 2 m	09936-00	1
Additionally			
	Tablet PC		1
	PHYWE measureAPP		1

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Set-up and Procedure

Setup

Caution:

1. You must be able to freely turn the tube with the thermometer. Do not let the sensor hit against the table or the rod.
2. Only lightly screw the universal clamp in the boss head.

Set up the experiment as shown in fig. 1.

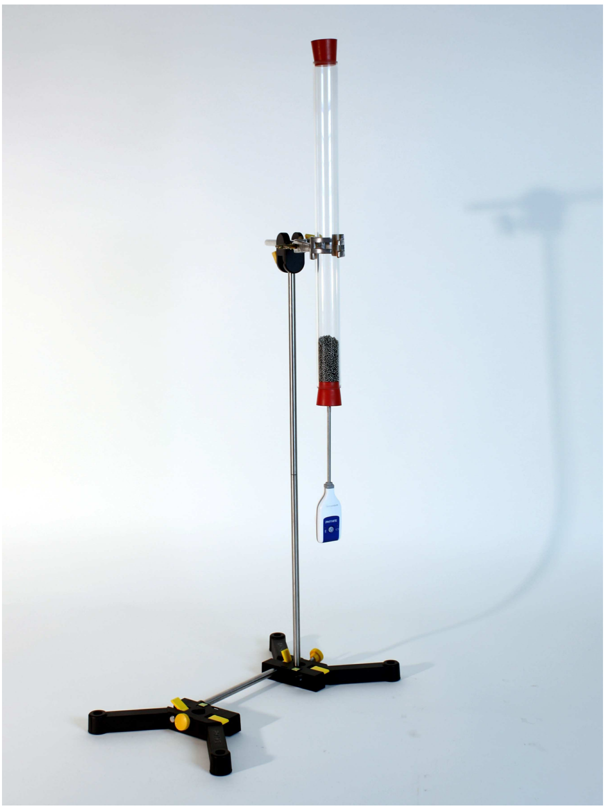

Fig. 1: Set-up

- Set up the support stand. Make sure that the rod is tightly secured.
- Push the sensor in the bored stopper so that the tip of it sticks out by about 1.5 cm. To be able to tightly close the tube and for more support, it is necessary to wrap tape around the temperature probe so that it is as big as the hole in the stopper (see fig. 2).

Fig. 2: How to secure the immersion probe in the stopper.

- Tightly close one side of the tube with the rubber stopper that holds the temperature sensor.

- Fix the tube to the support rod.
- Use the beaker to pour the pellets slowly into the tube. If you move to fast, the pellets will happily jump everywhere.

Procedure

1. Determination of the height of fall s of the pellets:

- Carefully introduce the measuring tape into the tube until it touches the pellets below.
- The share of the upper rubber stopper that juts in the tube must be subtracted from the value measured from the upper rim of the tube.
- Note the distance of fall s .

2. Falling experiment:

- Turn on the Cobra SMARTsense-Temperature. Open the „measure“ app and select the temperature sensor. Set the sampling rate to 1 Hz.
- Tightly close the the top of the tube with the stopper without a hole.
- Start data recording in measureApp, a measured temperature value is recorded every second.
- Wait approx. 100 s until the temperature display has stabilized – temperature sensor in the low position is in contact with the pellets, the tube in upright position.
- Turn the tube for 180° (backwards and forwards) 200 times with a jerky movement. Try to only hold the tupe at the stoppers. The pellets should not slide down the wall but fall down vertically as freely as possible. It might be nessessary to have your partner hold the stand for more stabilization.
- Wait a another 100 s until the measured value has stabilized, temperature sensor in low position is in contact with the pellets.
- End the measurement and save it.
- Pour the pellets back in the beaker so that they can cool down.
- While cooling, you can start with the evaluation.
- Repeat the measurement in the same way. The initial temperatures should almost be equal.

Evaluation

The evaluation is done in the report. Follow the steps below.

1. Select the regression tool to determine the initial temperature θ_1 of the pellets as well as the final temperature θ_2 of the pellets after 200 times of dropping, by placing a line with slope 0 as a mean for the constant parts of the curve (confere Fig. 4). θ_2 is the maximum temperature that was reached at the end of measurement. Supplement table 1 in the report.

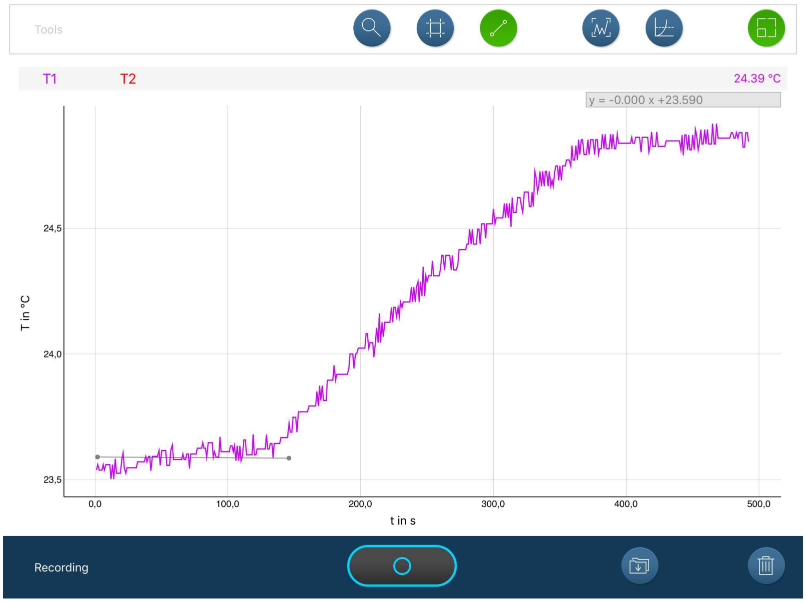

Fig. 4: Exemplary data curve with activated regression tool to determine the initial and final temperatures

2. Calculate each of the temperature differences $\Delta\theta = \theta_2 - \theta_1$ and supplement table 1.
3. Enter the height of fall s in table 2.
4. The pellets have a higher potential energy at the top of the tube that at the bottom of it. The difference is: $\Delta E_{\text{pot}} = m_{\text{steel}} \cdot g \cdot s$
   with the acceleration due to gravitiy $g = 9,81 m/s2$.
   When the pellets have been lifted this distance 200 times, then they have been given the mechanical energy E_{mech} calculated by:
   $E_{\text{mech}} = 200 \cdot E_{\text{pot}} = 200 \cdot m_{\text{steel}} \cdot g \cdot s$ (1)
   Calculate E_{mech} from (1), paying attention to the units (it is best to give everything in kg and m) – whereby for the mechanical energy [E_{mech}]=Nm and for the amount of heat [Q] = J; 1Nm = 1J). Enter your results in table 3.
5. Calculate in each case the change in the intrinsic energy of the pellets $\Delta Q = c_{\text{steel}} \cdot m_{\text{steel}} \cdot \Delta\theta$ using for the specific heat capacity of steel $c_{\text{steel}} = 0,45$ J/(g °C). Supplement table 3.
6. Calculate in each case the energy Q_V, that is given off as loss to the surroundings and the efficiency of the conversion process η. It is
   $Q_V = E_{\text{mech}} - \Delta Q$ and $\eta = \frac{\Delta Q}{E_{\text{mech}}}$.
   Supplement table 3 in the report.

Report: Conversion of mechanical energy into internal energy with SMARTsense

Results - Table 1 (9 points)

Use the regression tool as described in the evaluation to determine the initital temperature θ_1 of the pellets and the final temperature θ_2 of the pellets after falling 200 times. θ_2 is the maximum temperature which is reached at the end of measurement. Calculate all three temperature differences $\Delta\theta = \theta_2 - \theta_1$. Supplement table 1.

	θ_1 in °C	θ_2 in °C	$\Delta\theta = \theta_2 - \theta_1$ in °C
1. measuremen	23.59 1	24.79 1	1.2 1
2. measuremen	23.11 1	24.40 1	1.29 1
3. measuremen	23.29 1	24.49 1	1.2 1

Results - Table 2 (1 point)

Take down the distance of fall s in table 2.

Distance of fall s in mm	427 1
Mass of the pellets m_{steell} in g	120

Results - Table 3 (10 points)

Calculate the mechanical energy $E_{\text{mech}} = 200 \cdot m_{\text{Stahl}} \cdot g \cdot s$ and supplement table 3. Then calculate the intrinsic energy of the pellets ΔQ as described in the evaluation section as well as the energy lost to the surrounding Q_V and the efficiency η. Pay attention to the given and used units . Supplement table 3.

E_{mech} in J	101 1	ΔQ in J	Q_V in J	η in %
1. measurement		64.8 1	36.2 1	64.2 1
2. measurement		69.7 1	31.3 1	69 1
3. measurement		64.8 1	36.2 1	64.2 1

Evaluation - Question 1 (2 points)

Is the exact mass necessary for the determination of the efficiency?

Evaluation - Question 2 (3 points)

Which sources of error are there in this experiment?

Evaluation - Question 3 (3 points)

How effectively can potential energy be converted to intrinsic energy?

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