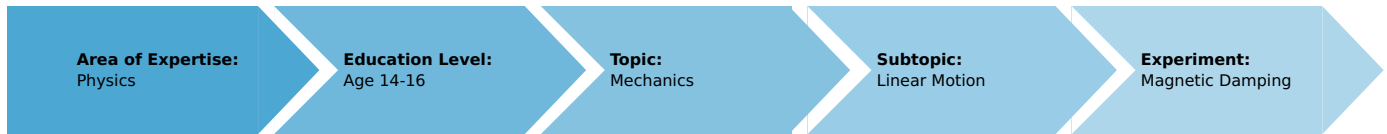


Magnetic Damping (Item No.: P6201100)

Curricular Relevance



Difficulty



Intermediate

Preparation Time



10 Minutes

Execution Time



20 Minutes

Recommended Group Size



2 Students

Additional Requirements:

- Tablet PC with DigiCart App

Experiment Variations:

Keywords:

Eddy current brake, Lenz's law, Magnetic field

Information for teachers

Introduction



Overview of experimental setup.

Educational objective

In this experiment the students learn something about the eddy current brake. It enables frictionless braking and is an application of Lenz's law.

Task

Let the DigiCart drive along an aluminium plate with a mounted magnet, which is mounted on the side of the track. Study the braking behavior within the different zones of the aluminum plate.

Prior knowledge

This experiment requires prior knowledge of electromagnetic induction and Faraday's law. Lenz's law should also be known.

Principle

If a change in the magnetic flux Φ is caused in a conductor, then according to Farady's law a voltage U_{ind} is induced in the conductor according to

$$U_{\text{ind}} = -\frac{d\Phi}{dt}.$$

This leads to so-called eddy currents. These eddy currents generate - like any current - a magnetic field, which counteracts its cause according to Lenz's law.

If the flux change in a metal is triggered by the passage of a magnet, magnetic fields are generated in the metal which counteract the cause. Since the cause lies in the passing magnet, the resulting magnetic fields are such that they inhibit the movement of the magnet and try to slow it down.

Equipment

Position No.	Material	Order No.	Quantity
1	DigiCart white		1
2	1.2 m track		1
3	Height adjustable holder		1
4	DigiCartAPP		1
5	Magnetic starter		1
6	Magnetic starter contact disc		1
7	Magnet for mounting on DigiCart		1
8	Aluminium plate with three zones		1
9	White round plastic spacers		2
10	Rubber bands		1
11	Spirit level		1

Safety information

For this experiment, the general instructions for safe experimentation in science teaching apply.

Introduction

Application and task

Application

This principle is used in a free-fall tower in the amusement park: Braking by the eddy current brake. If permanent magnets are used, this type of braking is very safe because it also works in the event of a power failure. Well then, have a good trip.

In this experiment you will learn something about the eddy current brake. It enables frictionless braking and is an application of Lenz's law.

Task

Let the DigiCart with a mounted magnet drive along an aluminium plate which is installed on the side of the track. Study the braking behavior within the different zones of the aluminum plate.

Equipment

Position No.	Material	Order No.	Quantity
1	DigiCart white		1
2	1.2 m track		1
3	Height adjustable holder		1
4	DigiCartAPP		1
5	Magnetic starter		1
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9	White round plastic spacers		2
10	Rubber bands		1
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Set-up and procedure

Set-up

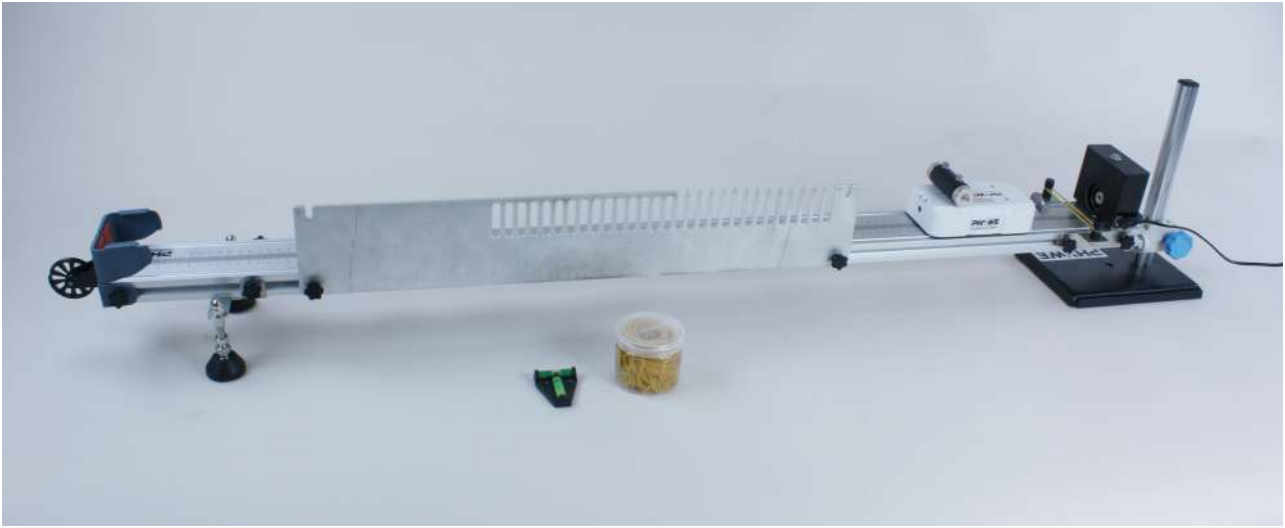


Figure 1: Overview of experimental setup.

- Mount the magnetic starter at the height-adjustable end of the track.
- Bring the track into a horizontal position using the spirit level. Then tighten two rubber bands on the black cylinders at the end of the track.

Note: The aluminium sheet has three zones. In the first zone the sheet is perforated and jagged, in the second zone the sheet is perforated and in the third zone it is plain.

- Mount the aluminium plate on the side of the track as shown in Figure 1 (DigiCart passes through zone 1 first, then zones 2 and 3). Use the white plastic discs as spacers between the track and the plate. They ensure that the DigiCart does not rub against the metal as it passes.
- Mount the magnet on the DigiCart as shown in Figure 1. Also attach the magnetic starter contact wheel to the DigiCart and place the DigiCart on the track.
- Start the DigiCart App.
- Select experiment 11 from the overview. The measurement window opens.
- Connect the DigiCart to the app (see Figure 2). Two steps are required. First, press the ON switch on the DigiCart for at least 3 seconds. Then open the connection window in the app via the bluetooth symbol (1.). The DigiCart should now be displayed there. If not, you can update the list by clicking on scan (2.). Now, one taps the DigiCart from the list once and establishes the connection via the connect button (3.). You can now hide the window again by pressing the close button (4.).

Magnetisch Bremsen

P6201100

Geschwindigkeit $v = 0.00$ m/s

Nr.	a_1 (m/s ²)	a_2 (m/s ²)	a_3 (m/s ²)
1.			
2.			
3.			
4.			
5.			

Dauer: 20 s
Intervall: 20 ms

Figure 2: Connecting to the DigiCart.

Procedure

- Figure 3 shows the steps for the measurement process.
- The velocity display (1.) shows the instantaneous velocity.
- If the measurement is not to be terminated manually, you can use the duration field (2.) to set the time when the measurement is to be terminated.
- The interval field (3.) is used to define the time between two measuring points.
- Activate the magnetic starter via the ON button and dock with the DigiCart to it. The rubber band is tensioned.
- Start the measurement by clicking on start measurement (4.).
- Now release the DigiCart from the magnetic starter by pressing the ON button again.
- Stop the measurement manually by clicking on stop measurement (5.) as soon as the DigiCart has passed through all three zones of the aluminium plate.
- Return the DigiCart to its original position and fix it with the magnetic starter.
- Perform another measurement. End it as soon as the DigiCart leaves zone 2.
- Perform another measurement. End it as soon as the DigiCart leaves zone 1.
- Click on select measuring range (6.) to select a range in the velocity time diagram in which the DigiCart is in zone 1. The selection is made by sweeping the interval with your finger. Then click on the save button (7.).
- Repeat the last step. This time select an area from zone 2 (only two curves left).
- Repeat the step. This time select an area from zone 3 (only one curve left).
- To delete a row from the table, touch it and then click the delete button (8.). By selecting a measuring range again and clicking on save, the row can be filled with new values.



Figure 3: Measurement procedure.

Evaluation

- The table in Figure 3 shows for each of the 3 measuring ranges (zone 1, zone 2, zone 3) the accelerations determined from the respective curves.
- In the first measuring range (zone 1) this was 0.06 m/s^2 for all measurements. In the second measuring range (zone 2) this was 0.17 m/s^2 . In the third measuring range (zone 3) it was 0.25 m/s^2 . Since this is a braking process, the values are negative. The magnitude of acceleration is highest in zone 3 and lowest in zone 1.

Since the resulting eddy currents in zone 1 cannot develop so freely (perforated and jagged), the magnetic fields that result in the deceleration of the DigiCart are not particularly strong. The acceleration is lowest in this zone. In zone 2, the eddy currents can unfold better because the jagged teeth are no longer present. This leads to stronger magnetic fields and the deceleration of the DigiCart increases. In zone 3, there are no more obstacles for the eddy currents. This is where the magnetic fields are strongest and where the deceleration of the DigiCart also occurs to be strongest.

Note: Tension further rubber bands to increase the initial speed of the carriage. Repeat the measurements. What do you notice?

Magnetic Damping

Results - Evaluation 1 (1 point)

Describe the process that causes the DigiCart to decelerate?

Score is granted based on the occurrence of the following keywords:

- The moving magnet changes the magnetic flux in the aluminium sheet. According to Farady's law, this leads to an induced voltage which causes the eddy currents.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

Results - Evaluation 2 (1 point)

How can the braking effect be reduced?

Score is granted based on the occurrence of the following keywords:

- If holes are made in the metal, the eddy currents are obstructed and the effect becomes smaller.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

Results - Evaluation 3 (1 point)

What other induction current applications are there?

Score is granted based on the occurrence of the following keywords:

- induction stove

Scoring Mode: Automatic Scoring with Keywords on Finding ONE

Results - Evaluation 4 (1 point)

What do you observe when you increase the velocity of the car?

Score is granted based on the occurrence of the following keywords:

- The brake accelerations increase. This is due to the fact that the change in the magnetic flux in aluminium is now greater. The braking effect is therefore velocity dependent.

Scoring Mode: Automatic Scoring with Keywords on Finding ONE