Magnetic Damped Oscillations

Equipment

Includes:

1	Motion Sensor	PS-2103A
1	Dynamics Track	ME-6995
1	Magnetic Damping	ME-6828
1	Spring Set	ME-8999
1	Rod base	ME-8735
1	45 cm Rod	ME-8736
	Required, but not included:	
1	Meter Stick	SE-8827
1	Calipers	SE-8710
1	Balance	SE-8723

Introduction

As the cart oscillates on the aluminum track, the magnets on the accessory bracket induce eddy currents in the track. This causes opposing magnetic fields that result in a drag force applied to the cart. The amount of damping is varied by changing the spacing between the magnets and the track. Systems are investigated that are Under Damped, Over Damped and Critically Damped.

Setup

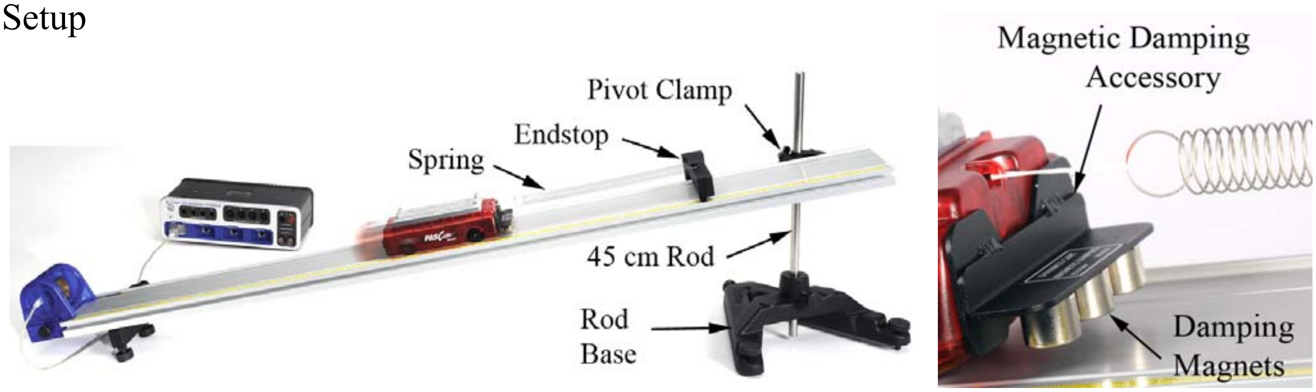

Figure 1: The Magnetic Damping Accessory attaches to the end of the cart that does NOT have the plunger. The steel bracket is held in place by the magnets inside the cart. It slides up and down to adjust the amount of drag: The closer the three silver magnets are to the track, the more damping there is.

1. Attach the endstop to the track as shown in Figure 1, then incline the track (about 30 cm) using the Pivot Clamp with the Rod Base and 45 cm Rod.

2. Connect the Motion Sensor to the interface and attach it to the track. Rotate the alignment knob on the side of the Motion Sensor so that it points parallel to the track. Make sure the switch on the top of the Motion Sensor is set to "cart."

3. In PASCO Capstone, keep the sample rate at the default 20 Hz. Create a graph of Position vs. time.

4. Attach the Magnetic Damping Accessory to the cart (see Fig. 2) and determine the cart mass including the accessory.

5. The Spring Set contains three each of four different springs. Start with one of the stiffer, longer springs. When new, this spring has a small dab of red paint on one end.

6. It is easier to attach the spring to the cart using a short loop of string as shown in Figure 2. The other end of the spring loops directly over the post on the Endstop.

7. The amount of magnetic damping is determined by the distance between the magnets and the track (see Fig. 3). Use some type of spacer (any non-magnetic material will work) to set the distance to about 8 mm. Slide the bracket down until the magnets are flush with the spacer, then remove the spacer.

8. Put both of the Cart Masses into the cart.

9. The spring should be stretched enough so that you can displace it from equilibrium (uphill) 15 cm and not have the spring go slack. Increase the incline of the track if needed.

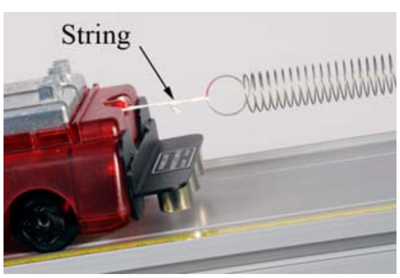

Figure 2: Attaching Spring to Cart


Figure 3: Magnet Spacing

Damped Oscillation Theory

The equation of motion for damped oscillation is given by

$$x(t) = x_o e^{-Bt} \sin(\omega t + \varphi)$$

where B = b/m, the ratio of the magnetic damping constant (b) to the mass of the cart (m). The angular frequency (ω) of the oscillation is related to the period (T) by

$$\omega = \frac{2\pi}{T}$$

Procedure

1. Displace the cart up the track about 15 cm from its equilibrium position.
2. Release the cart and click on Record. Allow the cart to oscillate up and down several times. Your data will look better if you stop recording before the cart stops oscillating.
3. Select a Damped Sine Curve Fit from the graph tool pallet. How well does it fit your data? You can use the Selection Tool to highlight only a portion of the data.

Drag Constant

1. Using ω from the curve fit, calculate the period of oscillation.
2. Use the Coordinates tool to measure the period directly from the graph. How does it compare to your value from part (4)?
3. Use the parameter, B, in the exponent of your curve fit and the mass of the cart to calculate the damping constant, b.

   B=b/m

4. Remove one of the masses and repeat. What values change?
5. Re-calculate the damping constant, b. How does it compare? Is it about the same value?

Critical Damping

1. Remove the masses from the cart. Replace the single stiff spring with two of the weaker long springs, as shown in Figure 4.

2. Adjust the incline of the track so that the cart is about midway between the Motion Sensor and the endstop. Note where the equilibrium position is.

3. Displace the cart up the track about 15 cm from its equilibrium position. When you release the cart, it will overshoot the equilibrium position and oscillate back and forth. Move the Damping Accessory down closer to the track (by about 1/2 mm) to create more drag. Try again. Does it still overshoot and then come back up the track?

4. Keep increasing the damping until it comes to a stop without overshooting the equilibrium position. You can record data to see the oscillation more clearly.

5. You want to find the least amount damping (biggest gap) that will still make the cart stop without overshooting. This is called Critical Damping.

6. You can delete unwanted runs using the Delete feature in the Experiment Control Bar.

Figure 4: Change to Weaker Springs

Analysis

For the following cases, always release the cart from the same initial position.

1. When you have the magnet spacing adjusted so that the least amount of damping (biggest gap) still makes the cart stop without overshooting, take one good run of data. Open up the Data Summary and re-name this run Critically Damped.

2. Slide the Damping Accessory up, increasing the spacing by about 1 mm so that the cart oscillates one or two times before coming to rest. Take one good run of data and re-name this run Under Damped.

3. Place a single piece of paper under the magnets, and then slide the Damping Accessory all the way down. Remove the paper. Take one good run of data and re-name this run Over-Damped.

4. For the Critically Damped run, how much time does it take for the cart to reach its equilibrium?

5. Note that for the Under-Damped run, the cart reaches the equilibrium point faster, but it overshoots. How much time does it take for the cart to come to rest at its equilibrium point?

6. In general, what is the condition in which an oscillating system damps out in the least amount of time?