Critical damping demonstration

This article was prompted by a post on Sputnik expressing a desire to demonstrate critical damping.

The work that follows was inspired by the excellent YouTube video demonstration here.

We have recreated the demonstration and then taken it a step further by using the first-rate, free, video analysis software, 'Tracker'. Find it here.

To book a place on our Tracker self-study course please go here.

Click here to find our tracker support material.


Figure 1 - Experimental set up.

Whilst not necessary we 3D printed a 'pivot' to mount on an 8 mm clamp rod. A simpler arrangement as shown in the original YouTube video would also work well.

The two, large neodymium magnets were placed either side of a half metre stick.

Please be mindful of the pitfalls and health and safety considerations of working with Neodymium magnets; avoid getting them stuck together as it is not easy getting them apart, risk of pinching, risk of fast moving fragments should the magnets be allowed to collide at speed, take care that the magnets do not interfere with other electrical/electronic devices such as pacemakers, hearing aids and mobile phones etc.

Using a smart phone, videos were taken of the pendulum at various magnet – aluminium separations. When the aluminium is exposed to a changing magnetic field a current is induced in the aluminium. Like any current in a conductor the eddy current will produce its own magnetic field. Lenz's Law states that the direction of the induced current will be such that it will oppose the change that caused it. These opposing magnetic fields are exploited to produce a braking force. The braking force is dependent on several factors including the magnetic field strength. The closer the magnet to the aluminium the greater the eddy current and the greater the braking force. Where damping is small the pendulum will oscillate about its equilibrium position. At 'critical' damping >>

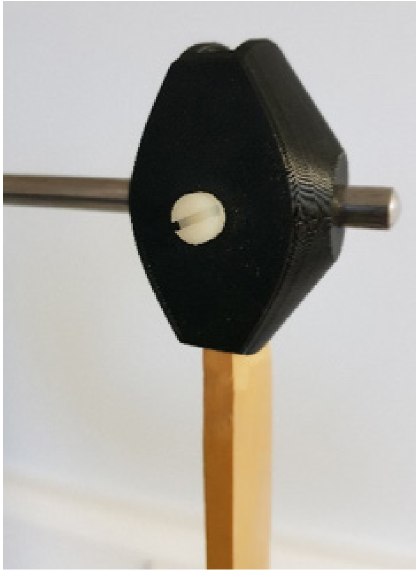
Figure 2 - Pivot details.


Figure 3 - Magnets attached to ½ m stick.

the pendulum will approach the equilibrium position in the shortest time without oscillation. Where the damping is large the pendulum will approach the equilibrium position in a much longer time period. The videos were then transferred to a PC and analysed in Tracker.

The data from three runs (2 mm, 8 mm, 30 mm) was then exported from Tracker and imported into Excel where the start times were made to coincide and the data plotted on one graph. This yielded the following results:

The grey (30 mm) trace in Figure 5 was produced with a magnet – aluminium spacing of 30 mm. Here the distance is large and so the induced eddy current and therefore damping force is small. The system is under-damped. The orange trace (8 mm separation) shows the damping force is (near) critical and the pendulum settles to its equilibrium position, without oscillation, in the shortest time interval. The blue trace (2 mm separation) shows over-damping and that the pendulum takes much longer to settle to its equilibrium position.

Our attempt to recreate the excellent video montage at the end of the YouTube video linked to above can be found here.

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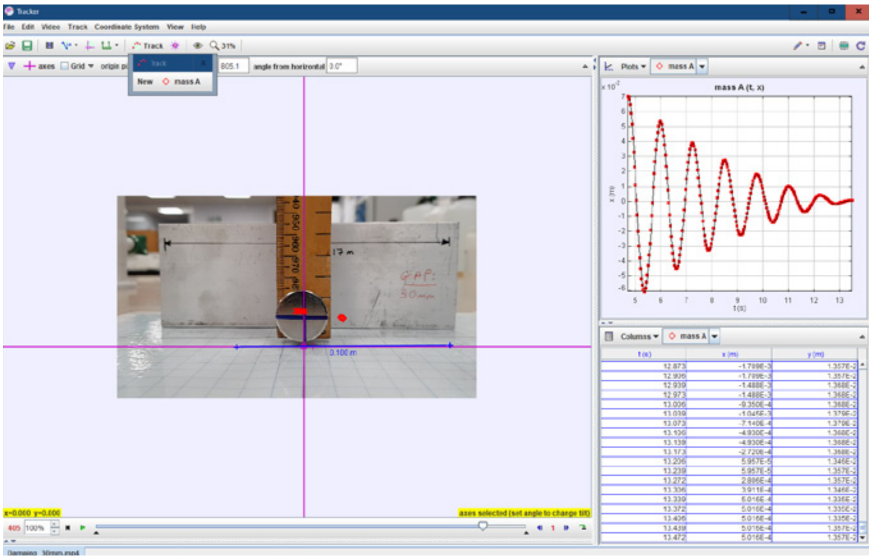

Figure 4 - Tracker screen showing a plot of x position against time.

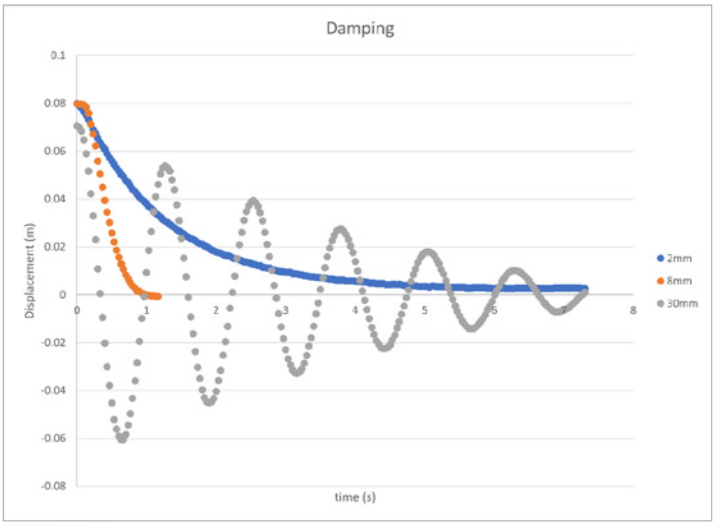

Figure 5 - Combined graph showing under, (near) critical and over damping.