Episode 306: Damped SHM

The ideas here are fairly straightforward. If energy is removed from an oscillating system (by friction), its amplitude will decrease. This usually follows an exponential decay pattern.

Summary

Demonstration: Water in a U-tube. (10 minutes)

Demonstration: A damped spring. (10 minutes)

Student experiment: Investigating damped SHM. (30 minutes)

Discussion: Exponential decay of amplitude. (10 minutes)

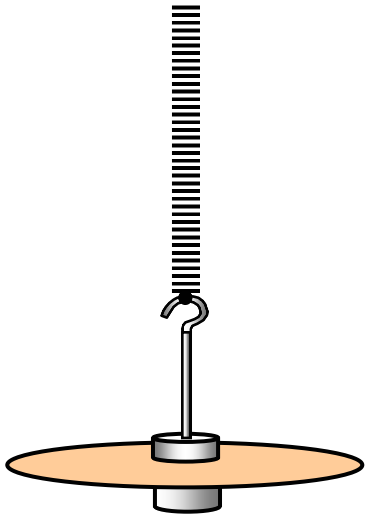
Discussion: Using damping. (10 minutes)

Demonstration:

Water in a U-tube

Show how water oscillates in a U-tube. The oscillation dies away quite quickly.

Friction due to viscosity will eventually dissipate the initial energy input to an oscillator and it will return to its position of stable equilibrium. This is called **damping**.



Demonstration:

A damped spring

Set up a suspended mass-spring system with a 'damper' – a piece of card attached horizontally to the mass to increase the air drag. Alternatively, clamp a springy metal blade (e.g. hacksaw blade) firmly to the bench. Attach a mass to the free end, and add a damping card.

Show how the amplitude decreases with time.

Safety:

If the hacksaw blade could be used as a weapon, have the teeth ground off by workshop staff.

Student experiment:

Investigating damped SHM.

Students can design their own arrangement for investigating damped SHM. They can investigate the pattern of decrease of amplitude (exponential decay), and whether the frequency is affected by damping.

Plot amplitude versus number of swings or against time. Use the graph to check for exponential decay of the amplitude using the constant ratio property.

The decay of the amplitude is exponential and careful measurement of the period may show that it is slightly less than the 'undamped' value. (This can be accounted for theoretically.)

Discussion:

Exponential decay of amplitude

Link this observation to other examples of exponential decay if already taught (RC circuit, radioactive decay, absorption of light by glass, thermal energy loss from a hot body etc.) to suggest what type of physics is taking place.

Exponential decay of the amplitude A implies that:

Rate of decay of maximum amplitude $A \propto$ present value of A.

Large amplitude implies high maximum velocity, which implies greater drag.

Recall that $PE_{MAX} \propto A^2$, so the total energy of an oscillator $\propto A^2$

When the amplitude has decayed to 1/2 its original value, the energy has been reduced to 1/4 of the original input and so on.

Discussion:

Using damping

For some oscillators (e.g. clocks) we want minimum damping; for others (e.g. a vehicle shock absorbing system) we want them to return to equilibrium as fast as possible. The latter requires a unique value of the damping ('critical damping') so that the system returns to equilibrium without overshooting; i.e. it gets to equilibrium in the minimum time without oscillating at all. Overdamping prevents over-shooting and thus any oscillations, but by making the damping large enough the system can take as long as you want to regain its starting equilibrium position.