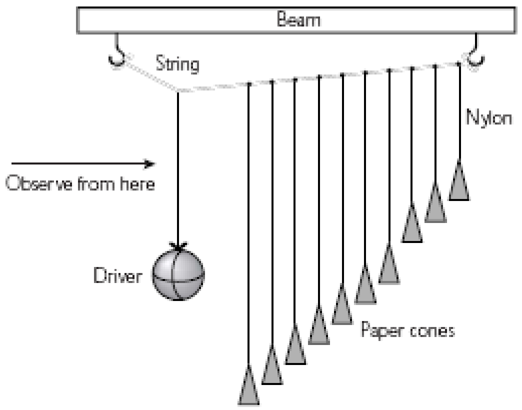
TAP 307- 1: Barton's pendulums

Apparatus

- ✓ heavy pendulum bob (e.g. brass or Plasticine, around 0.04 kg is suitable)
- ✓ several light pendulum bobs (e.g. Plasticine in small paper cones)
- ✓ string
- ✓ nylon fishing line or fine string or thread.
- ✓ clamp stands with G-clamps
- ✓ plastic curtain rings (if you wish to show damping effects)
- ✓ slide projector (if desired).

Set up:

Make one driver pendulum with a heavy bob and several light pendulums of various lengths with one length exactly matching the driver. Suspend all the pendulums from a string as below, and support the ends of the string firmly.



The demonstration is most effective in a darkened room with the cones brightly illuminated by a slide projector.

Students look along the line of the pendulums and observe what happens when the paper cones are at rest and then the driver pendulum is released from a widely displaced position.

The effective damping may be reduced by slipping plastic curtain rings over the cones and is easily done if the rings have a single cut in them.

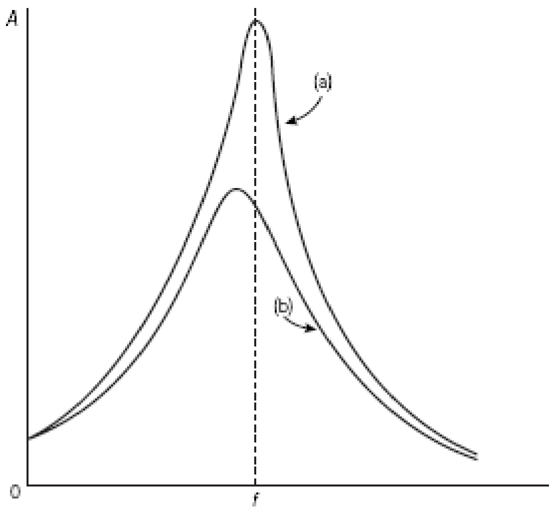
Practical advice

This classic demonstration shows the effects of resonance (and non-resonance). Draw attention to the initial transient oscillations that die away. Bring out the point that the pendulums then all oscillate at the driving frequency, but the ‘resonant’ pendulum oscillates with the greatest amplitude.

As an extension, you can also illustrate how damping affects resonance. Weight each paper cone, (e.g. with a plastic or metal ring, such as a curtain ring), so that it is less affected by air resistance. The transient oscillations take longer to die away, and when the ‘steady state’ is reached the amplitude of the resonant pendulum is larger.

You may wish to bring out the following points:

- The amplitude of the forced oscillations depend on the forcing frequency of the driver and reach a maximum when forcing frequency = natural frequency of the driven cones.
- The amplitude depends on the degree of damping, (see graph below).
- If damping is light, the frequency response curve peaks sharply at the resonance frequency, and the amplitude at resonance is very large. (See graph below.)
- If damping is heavy, the frequency response curve is broader, and the amplitude at resonance is not so large.
- Once transient oscillations of varying amplitude have died away a driven oscillator oscillates at the forcing frequency.
- At resonance the driver is one quarter of a cycle (π /2) ahead of the driven oscillator
- If $f_{nat} < f_{driver}$ then driver and driven are nearly in antiphase.
- If $f_{nat} > f_{driver}$ then driver and driven are nearly in phase.



The graph above shows two frequency response curves for an oscillator – in (a) there is very little damping but in (b) the oscillator is more heavily damped. The peak in (b) is broader, and it is the width of the peak that gives us a measure of damping.

Technicians note.

The wooden rod must be firmly clamped and be horizontal. It is very easy for the cones to tangle so the apparatus must be ready and set up in the classroom. (It is possible to manage without a wooden beam but it is easier to keep with one).

The lengths of the pendulums can be from a quarter to three quarters of a metre with the driver pendulum a half metre long. Nylon thread supporting the cones may be attached to the string by a half hitch or slip knot; this makes it easier to adjust lengths. The pendulums should be close together. Plasticine has been used successfully to secure the cones though a knot will suffice. If damping is to be shown plastic curtain rings that have 1 cut with a hacksaw so they can be slipped over the cones are good.

External references

This activity is taken from Salters Horners Advanced Physics, section BLD, activity 11 and additional sheet 9, with an adaptation of Revised Nuffield Advanced Physics experiment D15.