

TAP 301- 1: Oscillation circus

Observe a variety of oscillating systems and decide whether each exhibits simple harmonic motion. Try to identify what provides the inertia and what provides the stiffness of the system. Some systems lend themselves to detailed measurements, while others simply require observation.

Much of the data-gathering activity for oscillations will be made easier using the Motion Sensor and associated software from Data Harvest or other suitable sensor.

Apparatus

- ✓ 'simple' pendulum (small mass on a string)
- ✓ 'compound' pendulum (a rigid pendulum like a metre rule, with or without a mass on the end)
- ✓ 'torsion' pendulum (a mass hanging from a single wire, executing twisting oscillations)
- ✓ flexible strip of wood or plastic, clamped horizontally to a vertical support, oscillating in a horizontal plane
- ✓ inertia balance (a version of the previous oscillator)
- ✓ rolling ball on curved plastic tracking
- ✓ mass oscillating on a vertical spring
- ✓ large amplitude 'pendulum' (vertically rotating disc, pivoted at the centre with an off-centre mass clamped to it)
- ✓ test tube ballasted and floating vertically in water
- ✓ liquid in a large U-tube
- ✓ vehicle on an airtrack between elastic barriers
- ✓ 'catapulting' type oscillator (on an airtrack, or a trolley on a runway)

Optional

Access to a computer running the CD-ROM *Multimedia Motion*.

Sensing equipment and data-gathering software will be needed for recording the motion of some of the oscillators.

Study some, or all, of the following oscillating systems:

- 'simple' pendulum (small mass on a string)
- 'compound' pendulum (a rigid pendulum such as a metre rule, with or without a mass on the end)
- 'torsion' pendulum (a mass hanging from a single wire, executing twisting oscillations)
- flexible strip of wood or plastic, clamped horizontally to a vertical support, oscillating in a horizontal plane
- inertia balance (a version of the previous oscillator)
- rolling ball on curved plastic tracking
- mass oscillating on a vertical spring

- large amplitude 'pendulum' (rotating disc, pivoted at the centre with an off-centre mass clamped to it)
- test tube ballasted and floating vertically in water
- liquid in a large U-tube
- vehicle on an air track between elastic barriers
- 'catapulting' type oscillator (on an air track, or a trolley on a runway).

Observations

While you experiment on a particular oscillator consider the following questions:

Is the period constant (i.e. is it affected by the amplitude)? If the motion dies away quickly, you will need to think carefully how you will answer this point.

Can you identify separate stiffness (k) and inertia (m) components? If you cannot easily do this, can you pick out features of the system that behave like k and m (and try and say in a sentence or two why you found it difficult)?

What adjustments do you think you would need to make to the system to reduce its period (increase its frequency)?

Graphs of motion

Where feasible, obtain a trace showing how displacement varies with time. (You might find this the easiest way to answer the first question above.)

How would you find how the velocity and acceleration vary with time from such a trace?

Without doing any detailed measurement or calculation, sketch on the same (horizontal) axes graphs showing how the velocity and acceleration vary during the course of the motion.

Exactly how you take measurements and record displacement– time traces will depend on the data-gathering equipment you have available.

For example, if you are using a motion sensor you might

- use the associated software to produce velocity and acceleration traces for you as well – but don't rely on a computer to do all the work.
- Think how velocity and acceleration graphs relate to a displacement graph.

Extension

Use the *Multimedia Motion* CD-ROM to investigate the motion of a pendulum and obtain graphs of horizontal displacement, velocity and acceleration. Print out and keep a table of the numerical values of these quantities as well.

Practical advice

It is not possible to be very specific for apparatus, as what is provided will depend on local circumstances. A range of oscillators is suggested and it is recommended that as far as possible once the apparatus is assembled it is useful to keep it together and dedicate it to this activity.

Students explore a range of different types of oscillator. It is not envisaged that all the examples suggested are available, nor that students will attempt all that are put out – the range is not exhaustive and you will have your own preferences.

One suggested oscillator in the circus is a torsional oscillator (a twisting mass hanging from a single wire). This is worth including as it is one of the few examples of oscillations that remain simple harmonic for very large amplitudes (several complete revolutions).

Ideally some of the apparatus should be accompanied with sensing and data-logging equipment to enable displacement–time graphs to be displayed. For example, a motion sensor can easily detect the movement of a mass on a spring, and a potentiometer or other angle sensor can be used with a compound (rod-type) pendulum. More ambitiously, strain gauge sensors can be used with flexural oscillations.

Students should be encouraged to derive (or at least make rough sketches of) velocity and acceleration graphs before using any software that might generate them directly.

The oscillations will fall into three categories:

- (a) SHM (i.e. constant period) (within the accuracy of observations)
- (b) Approximately SHM, but departing at high amplitudes
- (c) Definitely not SHM.

It will probably emerge that (b) is the largest category. You might like to know the result that for pendulum-type oscillations, the period is

$$T = T_0 + \left(1 + \frac{\theta^2}{16}\right)$$

where T_0 is the period for very small amplitudes and θ is the angular amplitude in radians. For an amplitude of 1 radian (nearly 60°), $T = 1.063T_0$, and for very lightly damped oscillations it ought to be possible to detect the 6% increase in period.

The main point of the activity, though, is to demonstrate that many different oscillators behave in a way that is simple harmonic or nearly so.

A note on teaching SHM

SHM is sometimes considered to be a difficult area, probably because students can get overwhelmed by the maths and cannot see any direct use for their efforts. A context-setting discussion will largely avoid the second concern. As far as the first is concerned, we recommend that you use whatever approach to SHM you feel most comfortable with and which best suits your students

External reference

This activity is based on Salters Horners Advanced Physics, section BLD, activity 15