TAP 209-2: Ball bearings falling through a viscous medium

Apparatus:
✓ Length of glass or Perspex tube
✓ Bung for tube
✓ Glycerol (preferable) or wallpaper paste to fill tube
✓ Steel ball bearings
✓ Magnet (strong enough to allow you to fish the ball bearings out)
✓ Stopwatch(s) (or stop clock(s) for demonstration)
✓ Insulating tape

The tube should be at least 1 m long and 0.1 m in diameter if possible.

Wrap insulating tape around the tube at 10 centimetre intervals.

Time the descent of the ball bearing to find the mean speed between each of the markers. Record results in a table with the following headings:

<table>
<thead>
<tr>
<th>Distance interval /m</th>
<th>Time to fall through distance interval/ s</th>
<th>Mean velocity over distance interval / m s⁻¹</th>
</tr>
</thead>
</table>

Construct a velocity-time graph and a velocity-distance graph. These will show the ball bearing accelerating until it reaches terminal velocity. Repeating the experiment with ball bearings of
different mass and diameter will show that the terminal velocity of different bodies is not always the same. The experiment can be extended into an investigation of Stokes' law – how does the drag force depend on the size and speed of the falling ball?

Using the graphs, you should be able to answer the following questions:

How does the graph show when terminal velocity has been reached?

At what point in the fall did each ball reach terminal velocity?

If air is a fluid, is it correct to say that all bodies will fall at the same rate? Explain your answer.

Why did Galileo's legendary experiment in which he dropped two balls of different weights from the Leaning Tower of Pisa 'work'? Why did the balls hit the ground at the same time? You might want to refer to the ball bearing experiment in your answer.

(More generally) It is sometimes said that a mouse can be dropped from an aircraft and can land uninjured. Why might this be possible?

Why do skydivers fall more quickly when they roll themselves into a ball than when they have their limbs outstretched? Consider the forces on the skydiver in your answer.
Practical advice

Glycerol can be more difficult to clean out of the tubes afterwards. A batch of wallpaper paste could be made up and then diluted for each group progressively to give different viscosities.

Ball bearings dropped at the side of the tube drop at a different rate to those dropped at the centre. Think what effect this could have for swimmers in a pool or boat races.

Be safe

A problem with modern wallpaper pastes is the fungicide included; some students may have sensitive skin.

Do not use old engine oil, it is carcinogenic; fresh oil may be too dark to see the balls easily.

With either liquid students must take care not to suck fingers or get their pens/pencils covered with liquid and then suck them.

It is inevitable that as ball bearings are removed from the tube with the magnet that liquid drops off around the surrounding area. A wise precaution is to put the stand and tube on a tray covered with kitchen paper. The magnet also gets covered with the chosen liquid.

Care must be taken to ensure the bung does not come out of the tube.

Wash hands afterwards or as necessary.

Alternative approaches

It is possible to use light sensors and a computer to measure time intervals or indeed a webcam linked to the computer to record the fall of the ball bearings.

The Multimedia motion CD has a clip of a hammer and a feather falling on the Moon.

External references

This activity is taken from Resourceful Physics http://resourcefulphysics.org/