Relationship between Speed and Hydrodynamic Drag Forces during an Underwater Glide - Tutor Notes

For this tutorial you will need the MS Excel file **Linear Kinetics – Hydrodynamic Forces – Data.xls**. This contains data for the horizontal speed of a swimmer's hip, following a push-off from a swimming pool wall. The tutor can either ask the students to work with the data directly on a PC, or a paper copy of the data can be provided to the students. If working from a paper copy, the students will require calculators.

The 'direct difference' numerical differentiation technique involves using the velocity data from either side of the velocity value at which the corresponding acceleration value is required. This is to avoid a phase shift in the acceleration data. Note that the time interval use to calculate the acceleration is therefore 0.02 seconds.

As the swimmer's glide speed is decreasing, the acceleration values will be negative. Students could be reminded that the 'change in velocity' is computed as final velocity – initial velocity (and not vice versa).

The equation $F_D = ½ \times \rho \times A \times C_D \times v^2$ (simplified to $F_D = k \times v^2$) indicates that the drag force is proportional to the square of the glide speed. Students will verify this following completion of Table 1.

Note that the *k* values in Table 1 are reported as absolute (positive) values. As the *k* value is a combination of ρ, *A* and C_D it can be thought of as a measure of the swimmer's streamlining ability.

The *k* values range from 22.8 –25.2 $kg \cdot m^{-1}$ for this example. In theory (by definition) the *k* value should be a constant value for this swimmer, in this trial. However, factors such as measurement errors (inaccuracies) and the fact that the swimmer's body position changes slightly during the glide can explain why the *k* value varies slightly.

Students are asked to plot a graph of glide speed versus drag force and a graph of the square of the glide speed (v^2) versus drag force. If this is done in MS-Excel, the students could explore the nature of the relationships in more detail by using the 'Add Trend line' function. For example, a linear and then a 2nd order polynomial could be fitted to the glide speed versus drag force curve (and the R^2 value displayed) to show that the relationship is quadratic rather than linear.

A video clip of the push-off and glide is provided in the file **Linear Kinetics - Hydrodynamic Forces – Video.xls**