Impulse experiments using Electrolycra

This is an inexpensive, simple method of getting a force/time graph and comparing impulse with change in momentum.

The Higher course requires: *use of Newton's third law to explain the motion of objects involved in interactions. Interpretation of force/time graphs involving interacting objects. Knowledge that the impulse of a force is equal to the area under a force/time graph and is equal to the change in momentum of an object involved in the interaction.* Calculations on data obtained from the force/time graph are also required and this experiment works through them too.

Requirements

A 2 cm width, 11 cm length of Electrolycra™, 2 bulldog clips, 2 weights of 10 N, a piece of thick cardboard 13 cm by 10 cm, a voltage sensor, a variable 50 Ω potentiometer, two 22 Ω resistors, two 1.5 V batteries, a ball or bead of mass ~0.5 g and suitable interface for data logging, see Figure 1.

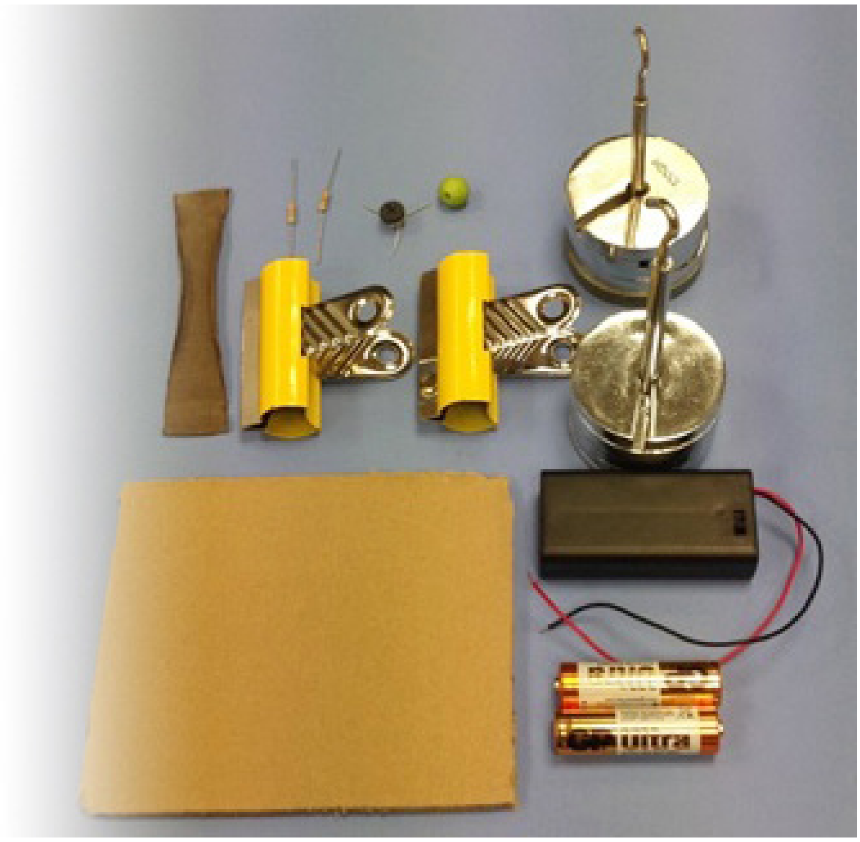

Figure 1 - Equipment required.

Constructing the voltage sensor

Cut a 10 cm by 13 cm rectangle from a piece of 5 mm thick cardboard. At the centre of the card use a pair of compasses to draw a circle with a radius of 5 cm. Cut out the circle, see Figure 2. Cut two, 2 cm long slots, 7 cm apart in one of the 13 cm long sides, see Figure 2. Extend the slots through only half the thickness of the card by a further 3 cm, see Figure 2. These slots keep the crocodile clips that connect the Electrolycra to the voltage sensor in place. Lay the Electrolycra across the centre of the circle so its longitudinal axis lies along the diameter of the circle. Stretch the Electrolycra by 1 cm and hold it firmly in place using the bulldog clips, see Figure 3. The Electrolycra must be stretch just enough so it displays a voltage that is proportional to its extension. >>

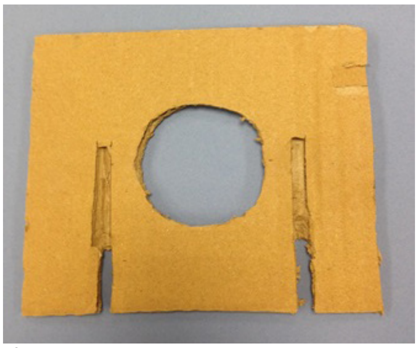

Figure 2

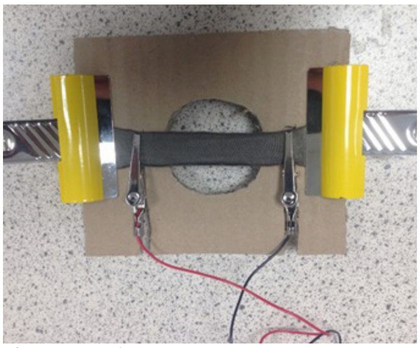

Figure 3 - Voltage sensor construction.

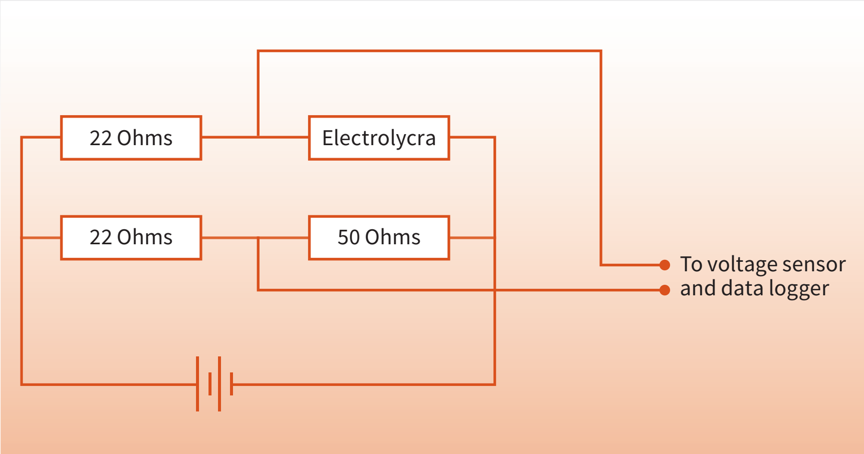

Figure 4

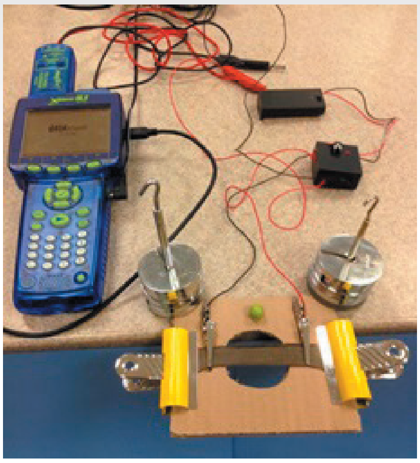

Figure 5

Construct a Wheatstone bridge as shown in Figure 4. Connect the Electrolycra into one arm of a Wheatstone bridge using the crocodile clips and connect the voltage sensor across the Wheatstone bridge so the off-balance voltage can be recorded, Figure 5. The off-balance voltage is recorded using a voltage sensor and a data logger. The voltage sensor needs to be calibrated so the voltage can be converted to a force.

Calibrating the voltage sensor
To calibrate the voltage sensor known masses are hung from the Electrolycra, see Figure 6. The easiest way to get the results is to record the off-balance voltage using the data logger. The reading tends to start high when the mass is first applied, then reduce. It is this initial high reading that should be used on the calibration graph. The masses must be placed with care, so that no extra force is applied by the mass dropping onto the carrier. The results are shown in Figure 7.

Calculations

The off-balance voltage against time graph for the bead dropped from a height of 2 cm is displayed on the computer, see Figure 8. The area under a force/time graph gives the impulse. The off-balance voltage can be converted to a force using the force/off-balance voltage graph, see Figure 7. A force time graph can then be plotted, see Figure 11.

The area under a force/time graph gives the impulse. Electrolycra exhibits hysteresis. It does not immediately return to its original state after being stretched by impact. The best estimate of the >>

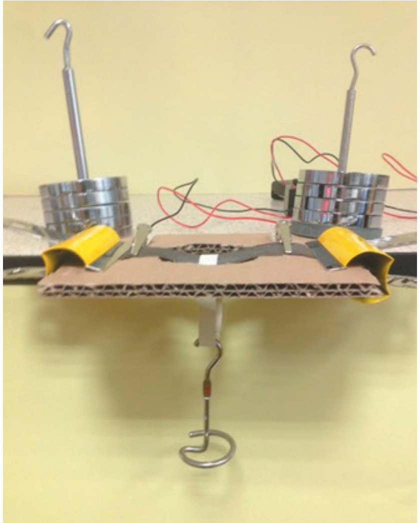

Figure 6

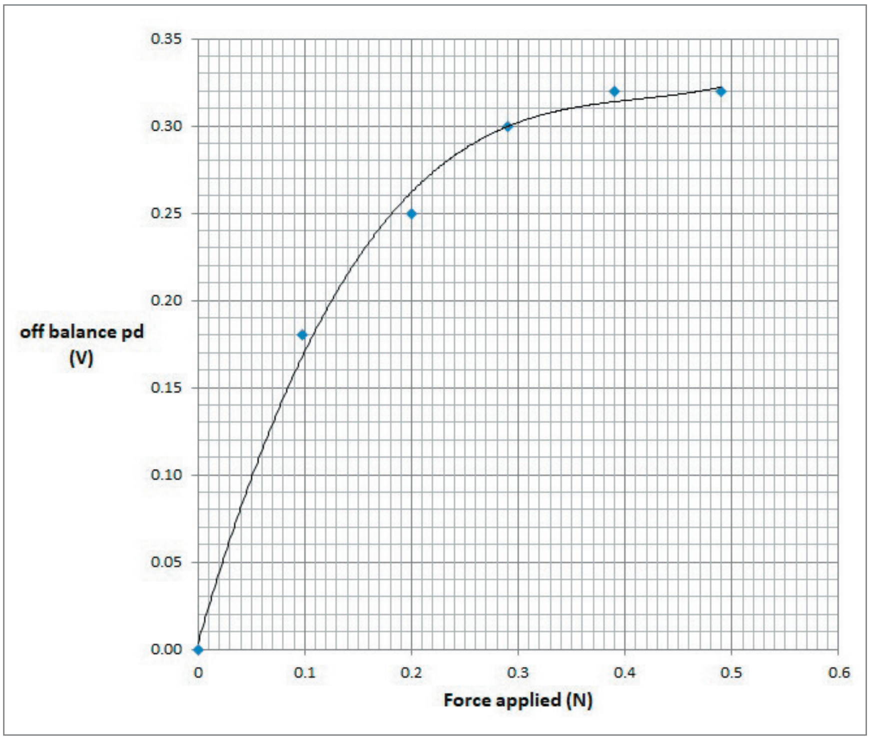

Figure 7 - The results.

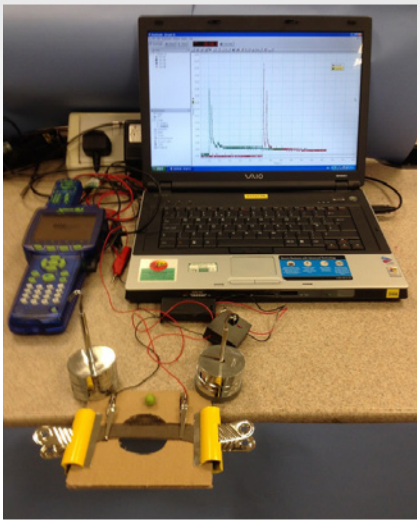

Figure 8 - The off-balance voltage against time graph for the bead dropped from a height of 2 cm is displayed on the computer.

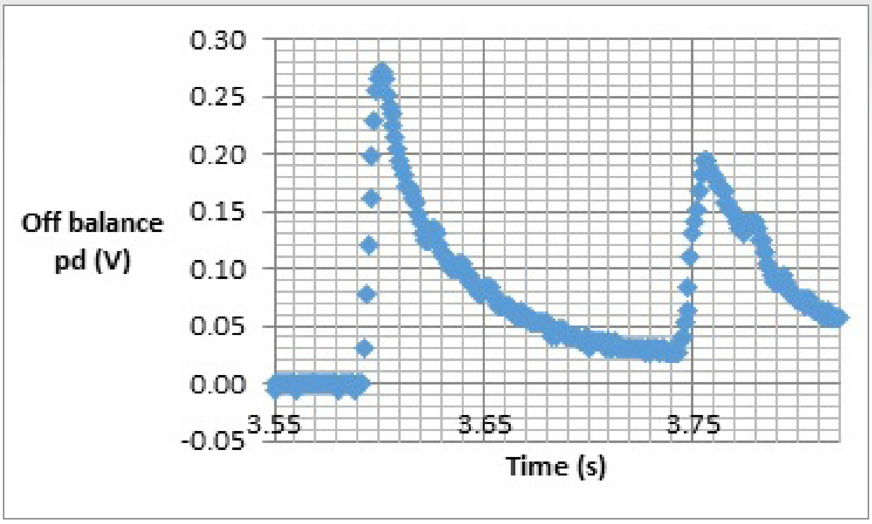

Figure 9 - Bead dropped from 2.0 cm.

area is found by doubling the area up to the peak of the graph in Figure 11 (the area bounded by the dashed lines).

Impulse = 2 x ½(0.009-0.001) x 0.21 Ns = 0.0017 Ns.

The mass of the bead was found, using a balance, to be 5.6 x 10^{-4} kg. Its change in momentum can be found if the height it is dropped from is know.

The bead was dropped from a height of 2.0 cm.

The loss of gravitational potential energy is assumed to be equal to the gain in kinetic energy.

$mgh = \frac{1}{2}mv^2$ giving, on rearrangement $v_1 = \sqrt{(2gh)} = \sqrt{(2 \times 9.81 \times 0.02)} = 0.6\ ms^{-1}$

The bead bounced on the Electrolycra and reached a height of 1.0 cm. This can be deduced as when the bead was dropped from a height of 1 cm the peak voltage was 0.2 V, see Figure 10.

$v_2 = \sqrt{(2 \times 9.81 \times 0.01)} = 0.4\ ms^{-1}$.

Taking the downward direction as positive, v_1 as the initial velocity and v_2 as the final velocity the change in momentum is given by:

$\Delta mv = m(-v_2 - v_1) = 5.6 \times 10^{-4} (-0.4 - 0.6)\ kg\ ms^{-1} = -6 \times 10^{-4}\ kg\ ms^{-1}$.

Summary

Comparing impulse with change in momentum, they are of the same order of magnitude rather than equal. Several assumptions have been made throughout the analysis and, as a further teaching point, these assumptions can be discussed with students. <<

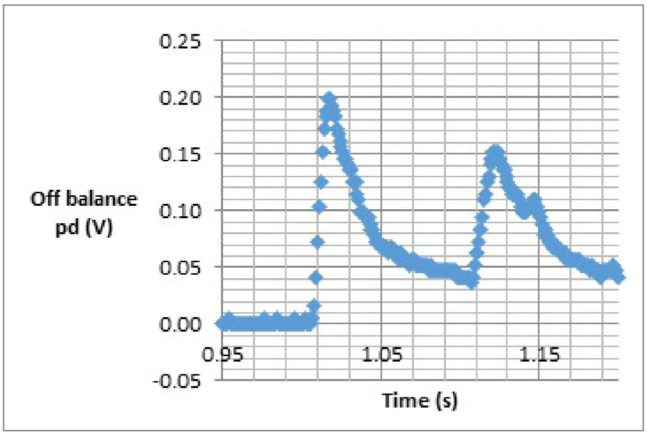

Figure 10 - Bead dropped from 1.0 cm.

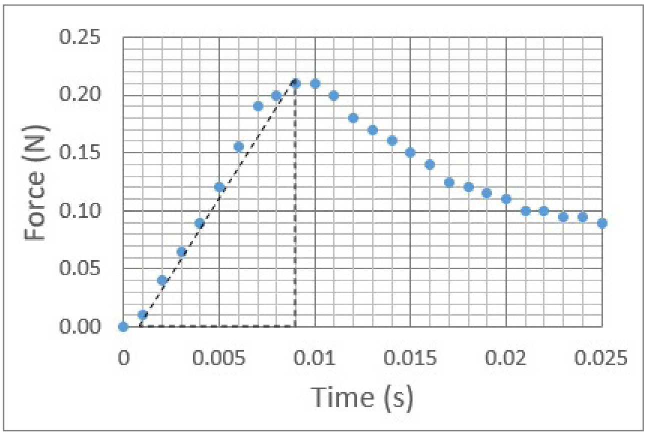

Figure 11