How smart is

A car like the Triumph Herald (Figure 1) probably had around 50 m of wiring in it and nothing that would be identifiable as a computer on board.

Modern cars may have a kilometre of wiring and more computer memory dedicated to stopping a CD from jumping than was used in an Apollo space capsule. Whilst car technology developed radically over the last three decades, the humble dynamics cart resolutely stuck to a formula of "box with three or four wheels and maybe a spring-loaded plunger". Recently, things have begun to change. Welcome to the Tesla Model-X of physics trolleys, the Pasco Smart Cart (Figure 2).

Figure 1 *- Triumph Herald.*

Like a Tesla, the Smart Cart needs to be charged, though not in this case to make it move. Its internal battery powers accelerometers, gyros, a force sensor, a position sensor linked to the wheels and the circuitry to enable it to connect wirelessly to a Bluetooth-enabled PC or tablet. Our investigations were carried out using iPads and Android tablets running the free Sparkvue app.

Figure 3 shows a Smart Cart on a slope, attached to a spring. We logged position (from the wheel sensor) and acceleration (from the on board accelerometer) versus time (Figure 4).

The data shows that displacement and acceleration are 180 degrees out of phase. You may be wondering why acceleration is centred around 2.0 ms^{-2} and not zero. This is because accelerometers will measure a component of gravitational acceleration that offsets all readings unless the software is set to remove it.

More than one Smart Cart at a time can be connected to a tablet. This makes momentum investigations easy. Figure 5 shows the velocities during a collision between a Smart Cart and an initially stationary less massive trolley (you can work out the ratio of masses from the plot).

Sparkvue can also access your tablet's internal sensors. We exploited this feature by placing a tablet on top of a Smart Cart and moving it in front of two laptop speakers that were fed from another tablet that was running a signal generator app. We were able to plot maxima and minima caused by the interference of the sound from each speaker (Figure 6) by graphing sound intensity versus position.

Pasco also has a device called an Airlink that allows other sensors to connect to a tablet via Bluetooth. We were able to investigate the inverse square law for light using a light sensor mounted on the cart and its inbuilt position sensor.

Crumple zone experiments were also tried. These require a fast data capture rate - 100 readings per second is about as low as you can go. Whilst we were able to carry out some investigations, older Android tablets baulked at the task.

Figure 2 *- A brace of Pasco Smart Carts.*

your cart?

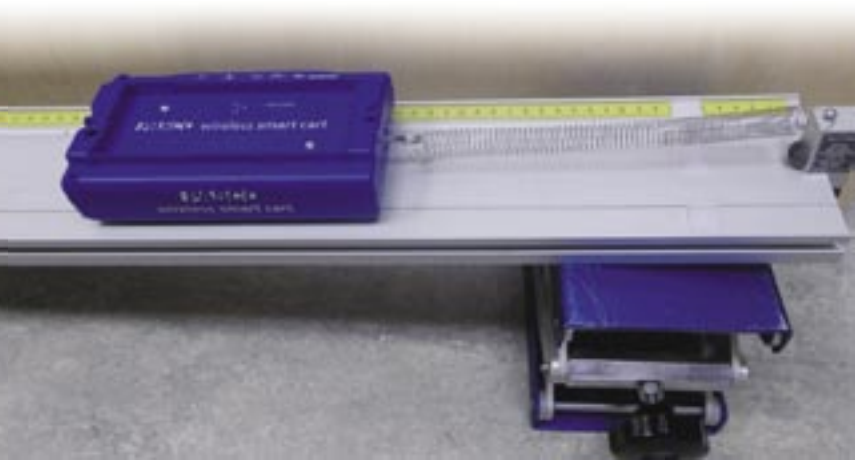

Figure 3 *- Smart Cart set up to investigate simple harmonic motion.*

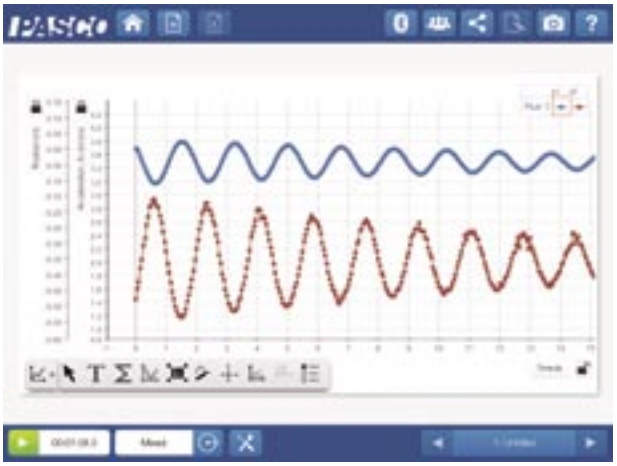

Figure 4 *- Position (blue) and acceleration (red) versus time.*

When we demonstrated the Smart Carts at a course, one participant was unhappy. He felt that the cart and software were performing some of the tasks students should be doing themselves, for example graph plotting. It is certainly possible to use this technology badly. Tongue in cheek, we posted on our social media outlets an inverse square law experiment that produced a linear plot in 11 seconds as the cart and light sensor was moved back from a lamp. Such a demonstration would be of little educational value without explanation, but if the inverse square law had been established with students, it could be a quick way of investigating whether the light source behaved as a point at close distances. Plotting a velocity/time graph of a cart running down a slope does not teach a pupil to plot a graph, let alone calculate a velocity. However, when these skills have been developed, this equipment makes it very easy to investigate the effects of changes to conditions. What change would we expect in the gradient of the velocity time graph if we made the slope steeper? What would be the effect of increasing friction? Predict what the sound intensity graph would look like if we used sound of a higher frequency, and so on.

At the time of writing, Smart Carts cost a little under £150 each, excluding VAT. They are sold by Scientific and Chemical, who are distributors for Pasco kit in the UK. ◀

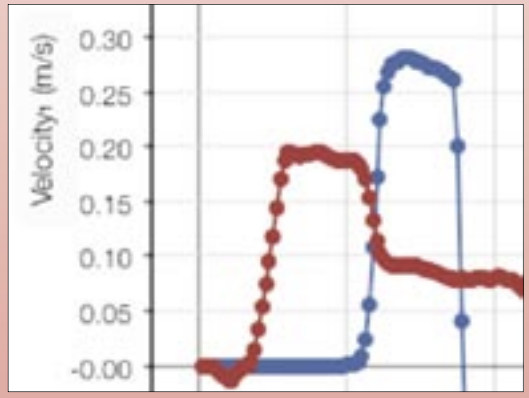

Figure 5 *- Collision analysis.*

Figure 6 *- Sound interference.*