Dynamics with Dongles - A Wireless Acceleration Sensor

The *Vernier WDSS (Wireless Dynamics Sensor System)* is a wireless sensor that can measure acceleration in 3 axes and has force and altitude sensors. It can also act as a datalogger to record data. Data transfer is wireless, via *Bluetooth*. The sensor is supplied with *Logger Pro software* and a Bluetooth dongle that plugs into the USB port of a computer.

Figure 1 - The Vernier WDSS

Our first experiments involved attaching the sensor to a PASCO cart, found by SSERC to be the *Rolls Royce* of dynamics trolleys [1], and letting it roll down an inclined plane. Rather than obtaining the constant acceleration associated with a constant slope, the acceleration appeared very jittery. The trace in Figure 2 shows a period of acceleration when the cart was pushed up the slope, then allowed to roll back down. We believed the jittering to be due to imperfections in the cart's wheels, bearings and in the runway. Thus, we expected it to be less when the vehicle was moving slowly. This is borne out by our results.

The cart stops momentarily at roughly 3.75 s (Figure 3). Note that the acceleration before the cart stops has a slightly greater magnitude than that as it runs back down the slope. This is because friction is in the same direction as the component of weight when the cart travels up the slope but is in the opposite direction as it descends. Data was copied to *Excel* and accelerations were averaged over the period where readings were not subject to jittering. The experiment was repeated for different gradients, with the sensor zeroed on the slope prior to each run. In all cases, measured average accelerations lay within ± 0.07 ms^{-2} of theoretical values. It should be noted that the accelerations produced by a freely moving cart on an inclined plane represent only part of the range measurable by this sensor. The manufacturer's data suggests a range of ± 50 ms^{-2}, with an accuracy of ± 0.5 ms^{-2} and a resolution of ± 0.04 ms^{-2}.

Logger Pro software has a smoothing function, but even this was unable to remove the large fluctuations in acceleration. That said, the suppliers do not suggest that the wireless sensor is primarily designed for the type of experiment where a constant acceleration would traditionally have been measured using a double mask and light gate connected to a microprocessor or interface.

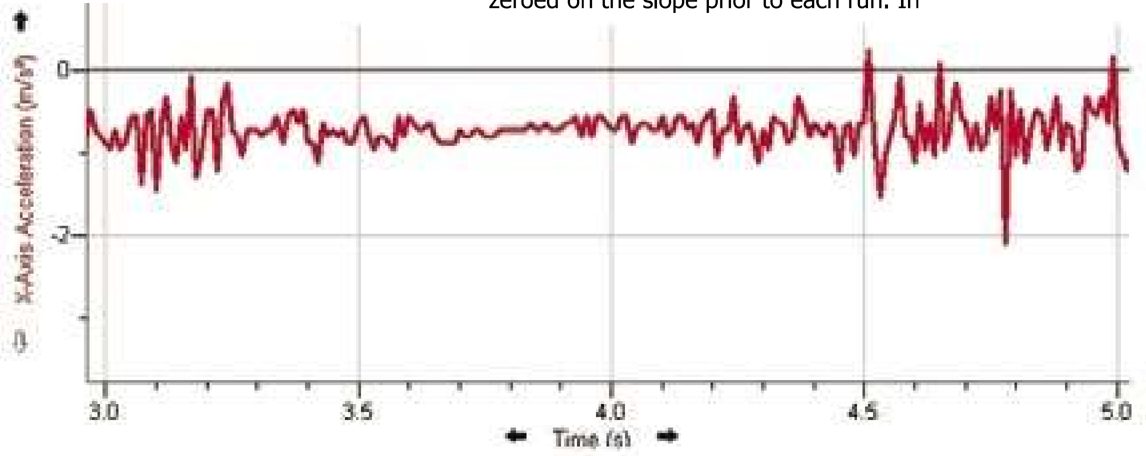

Figure 2 - Cart pushed up runway, allowed to stop and return back down

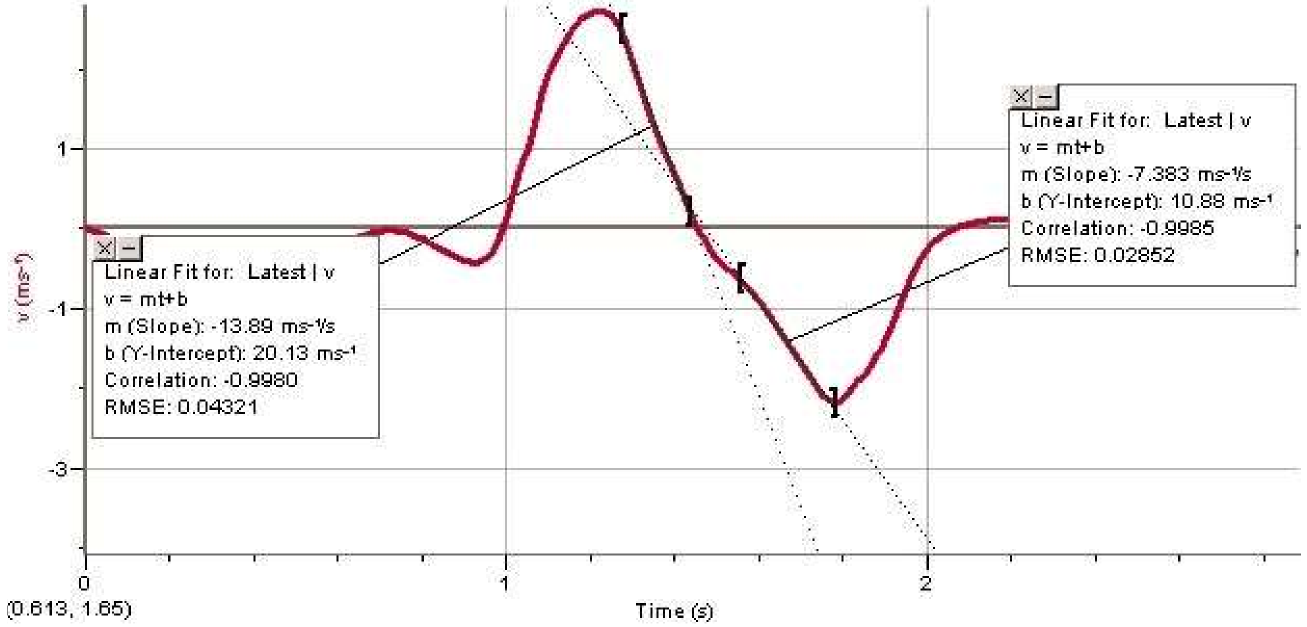

Figure 3 - Jumping (velocity versus time)

In fact, the sensor does not need to be moving to record an acceleration. If the device is zeroed on a flat surface then stood on end, it will register an acceleration of around 9.8 ms^{-2}. Placed on a slope of 30° to the horizontal, it should measure an acceleration of 4.9 ms^{-2}.

We then carried out a number of investigations using the sensor. Some, by their nature, were qualitative rather than quantitative.

Having zeroed the unit with the x-axis pointing upwards, it was placed in the tester's shirt pocket. The tester then crouched and jumped upwards, landing on the floor. We were also able to plot velocity / time graphs as *Logger Pro* can integrate acceleration with respect to time. (Figure 3)

Once again, the acceleration when travelling upwards is greater than that when travelling downwards due to the direction of the frictional force in each case.

We do not have space here to cover all the investigations we carried out. These included freefall, simulated bungee jumping, simple harmonic motion, f=ma (dragging the unit around by a string attached to the force sensor) and remote data logging on car and train journeys. Full details are given in the on-line version of this article [2].

We used the WDSS to investigate the relationship between angular velocity and central acceleration. It was mounted on a *PASCO turntable* that was driven by an electric motor, as shown in Figure 4.

The sensor is clearly marked with the position of the accelerometers, allowing us to measure their distance from the axis of rotation. Angular velocity was measured using a *PASCO Smart Pulley* and photogate connected via a *Science Workshop interface* to a laptop running *Data Studio*. The set-up allowed us to produce central accelerations of up to 60 ms^{-2}, above which the turntable, though held in place by bricks, attempted to amble round the laboratory bench. 60 ms^{-2} is in any case at the limit of the stated range of the WDSS. Data for acceleration was captured at a rate of 500 readings per second. The 5000 readings for each run were averaged. A graph of central acceleration versus angular velocity squared is shown below (Figure 5).

Figure 6 - WDSS mounted on radio-controlled car

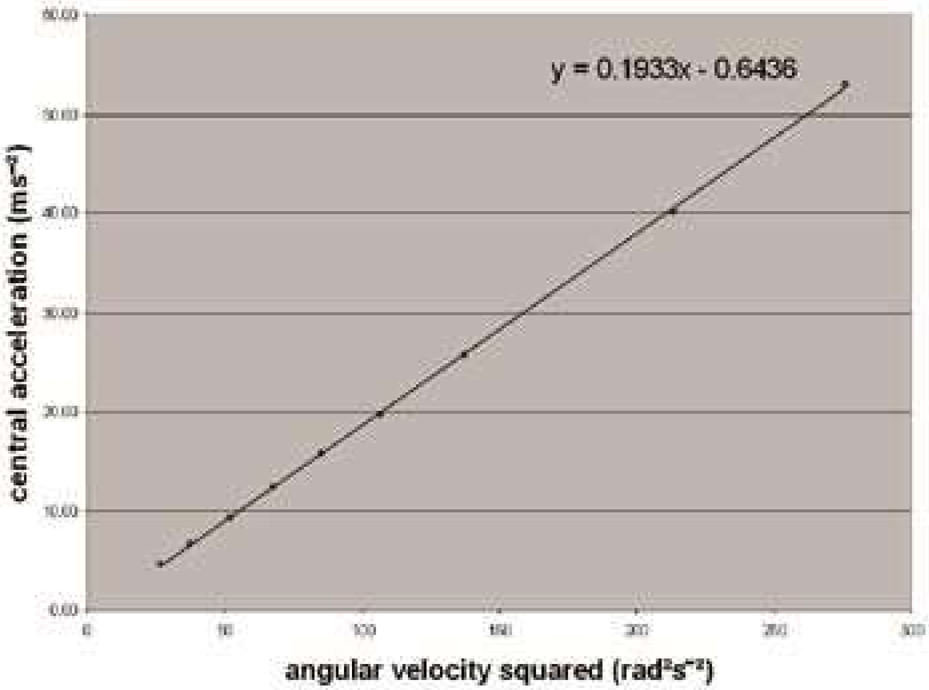

Figure 5 - Central acceleration experiment

Note that the gradient of the line should be the radius of rotation, measured by us as 192 mm ± 0.5 mm. We felt that the use of the Vernier Wireless Sensor System greatly enhanced the investigation of this relationship. Angular velocity could have been determined by timing a fixed number of revolutions, had a *Smart Pulley* been unavailable.

Borrowing an idea we had heard of from Steve Emery of IDS [3], a company that supplies the Vernier Wireless Sensor, we mounted the unit on top of a radio-controlled car. This was done using the *PASCO cart adapter*, held on to our model with self-tapping screws.

Bluetooth and radio-control frequencies do not interfere with one another. The natures of the drive system of the car and the floor it was running on were such that a graph of acceleration versus time was too noisy to interpret. We had more success integrating acceleration to obtain a velocity / time graph.

Figure 4 - Sensor mounted on PASCO turntable

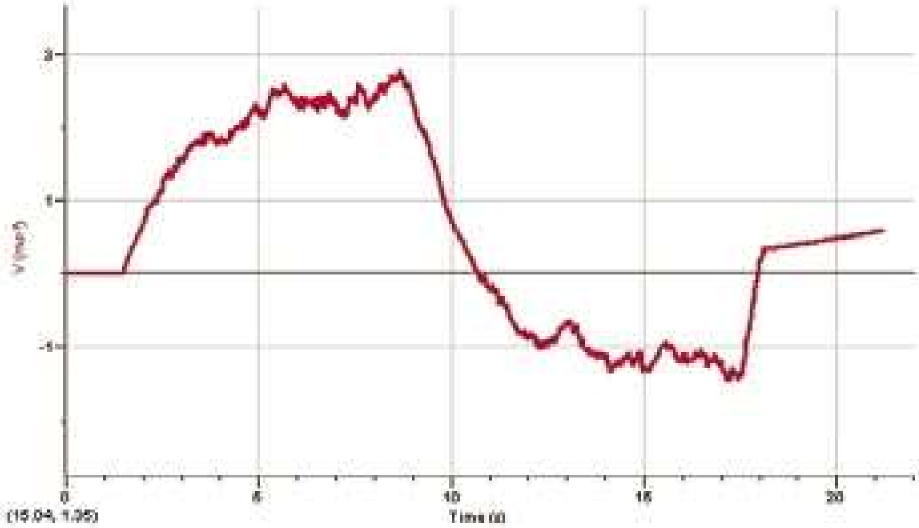

Figure 7 - Radio controlled car accelerating, slowing then reversing

Our twelve year-old driver had some experience of negative numbers but no formal physics training. Nevertheless, he was quickly able to relate the graph he obtained to the course he had driven. Note, however, the apparent increase in velocity after around 18 s. The car was in fact at rest at this point but unless it is stationary on a gradient identical to that at which it was zeroed, the sensor will interpret the slope as an acceleration.

Following advice from the leaflet supplied with the WDSS, we investigated crumple zones. With the WDSS mounted on a PASCO cart, we monitored acceleration during collisions with a fixed wooden block. The cart was fitted with various bumpers and crumple zones.

It was placed on a runway of fixed length and height and always released with the front of the bumper at the same point on the runway.

We found that we had to limit the cart's run to 50 cm along a 4° slope to avoid the acceleration reading going beyond the sensor's limit when crashing into the wooden block.

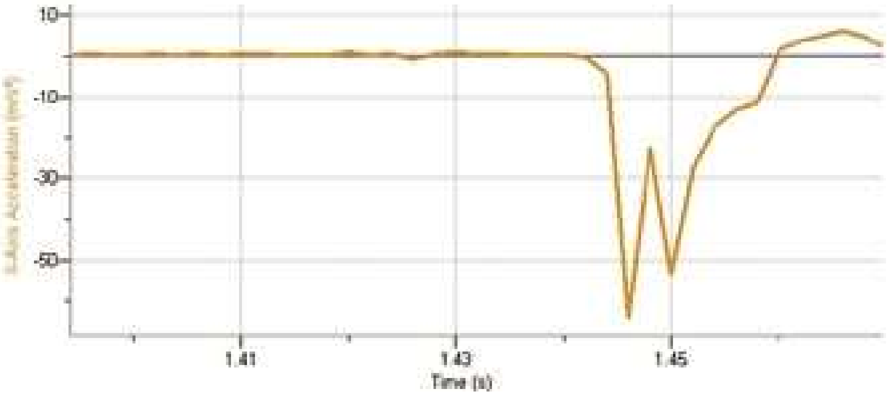

Figure 9 - Acceleration during crash into wooden block

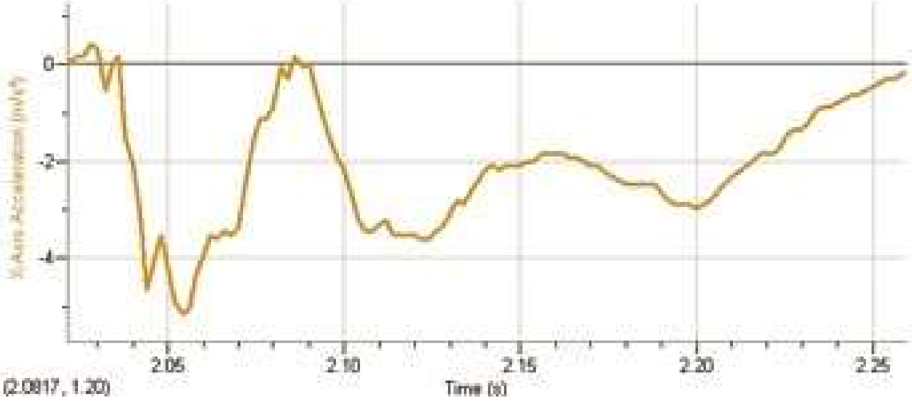

Figure 10 - As Fig 9, but with cart fitted with card crumple zone. Note different scales on graphs.

Figure 8 - Pimp My PASCO Cart

Circumstances did not permit us to verify the manufacturer's assertion that the unit would be suitable for the analysis of motion on fun-fair rides but we see no reason to contest this claim.

Conclusion

The Vernier Wireless Dynamic Sensor System was an effective tool for the qualitative analysis of collisions, real life situations such as jumping or car travel and modelled ones like bungee jumping. Its sensitivity made it largely unsuitable for experiments with trolleys on runways. Good, quantitative data was obtained by averaging acceleration and by integrating acceleration to give change in velocity. Relationships such as that between force and acceleration, and angular velocity and central acceleration could be investigated effectively. Used with care, the *WDSS* would help pupils to understand velocity / time graphs. The supplied software, Logger Pro, was very versatile.

References

[1] *SSERC Bulletin 181*

[2] http://www.sserc.org.uk/members/SafetyNet/bulls/222/contents.htm

[3] http://www.inds.co.uk