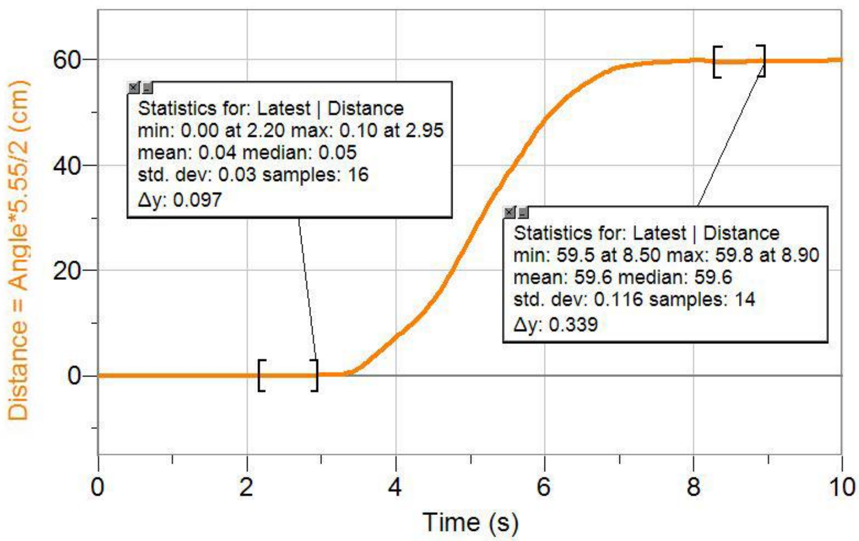
A model odometer

Odometers are the instruments in vehicles that record the distance travelled. If you have a Vernier rotational motion detector you have a model odometer that will measure and record lengths on a lab bench.

Fig 1 – a Vernier angular motion detector with a plastic disc attached.

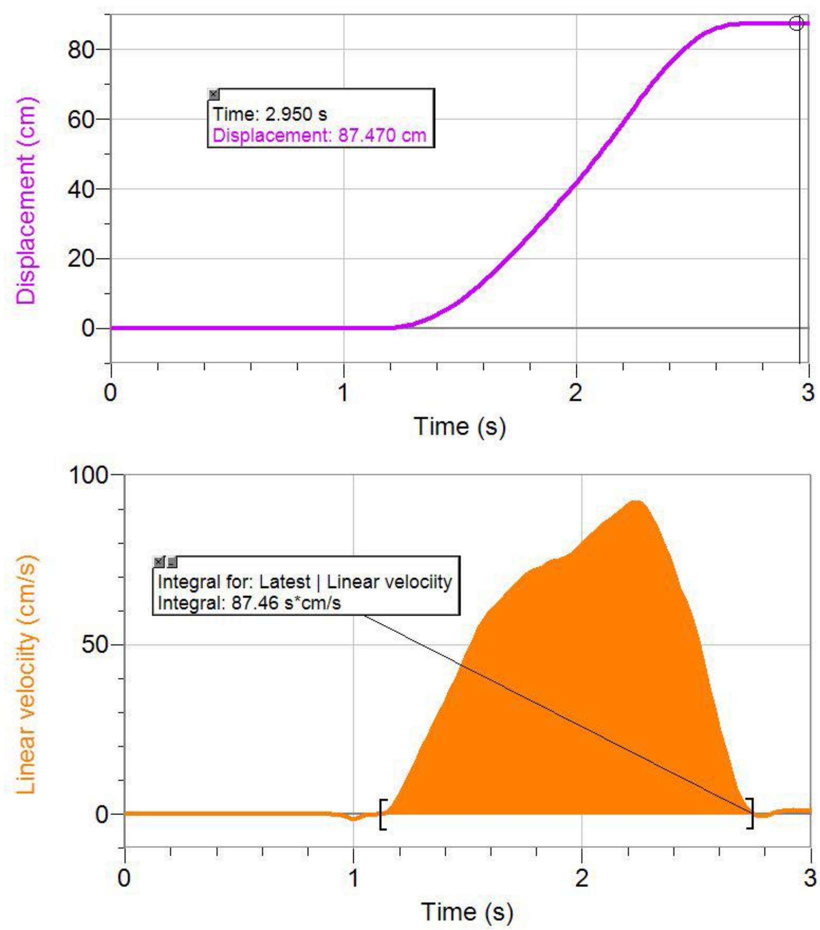
The diameter of the disc is measured as 5.55 cm. A 60 cm rule is laid on the bench and the wheel is rolled the length of the rule. The probe is designed to plot angle θ in radians as a function of time in Logger Pro. To plot distance we multiply measured angle by the radius in a *New Calculated Column*. The result is shown below.



Graph 1 – the model odometer records the correct distance travelled to within ± 1%.

As with odometers in cars, the accuracy of the model depends on the exact radius of the wheel. Inflating the tires on a car enlarges the wheel slightly and leads to an odometer reading that underestimates the length of a particular journey.

The graphs below take the demonstration one step further. The angular motion detector plots angular velocity ω as a function of time. Linear velocity has been calculated as $r\omega$.



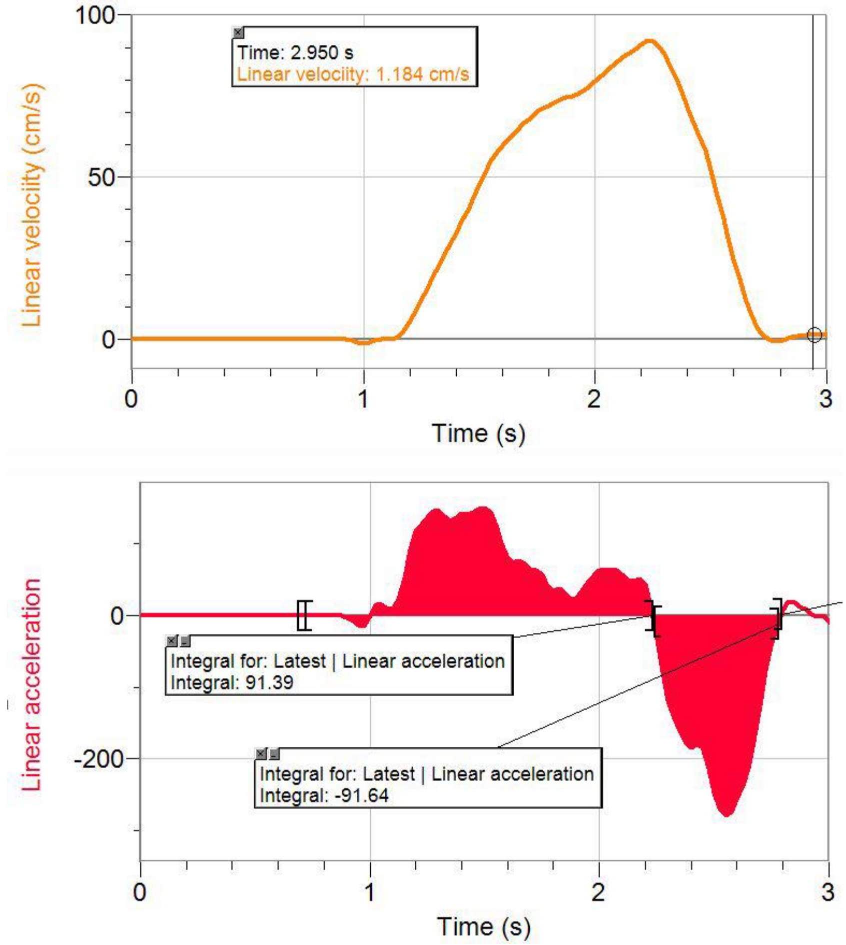
Graph 2 – the model odometer records displacement and velocity as functions of time.

Net displacement from 1 to 3 seconds is given by the velocity time integral as 87.5 cm in excellent agreement with the direct reading on the upper graph.

Note

Please note that this is a demonstration in kinematics: a demonstration of the consequences of the definitions of variables, not a demonstration of physical laws. The equality of the integral and the displacement reading is a test of the numerical integration function of the computer with 40 data points per second.

A third calculated column allows the acceleration-time graph to be plotted.



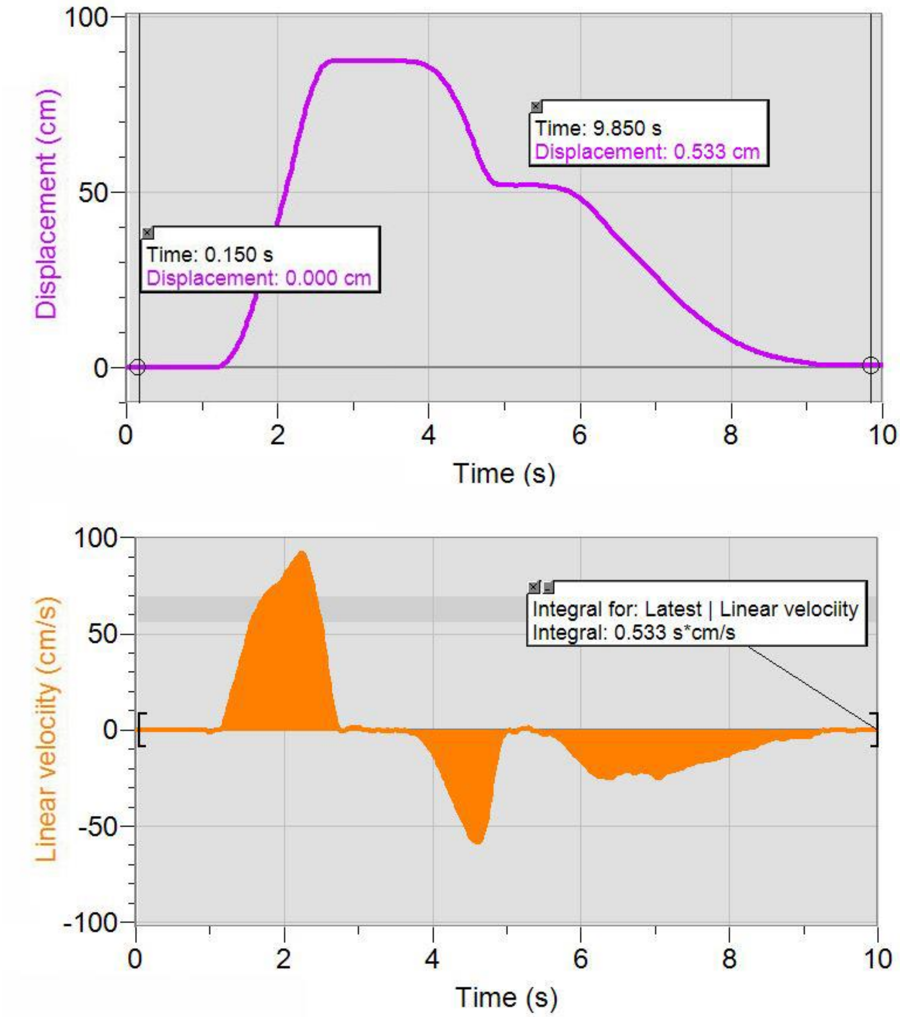
Graph 3 – linear velocity and acceleration plotted as functions of time.

From 1.0 to 2.3 seconds the velocity is increasing and the acceleration is positive. The acceleration integral represents the increase in velocity from zero to just over 90 cm/s^2. The acceleration drops to zero momentarily as the velocity becomes constant and begins to reduce. From 2.3 to 2.8 seconds the acceleration is negative.

The area above the zero line on the acceleration graph is positive and the area below the lone is negative. Within errors the two integrals add to zero, confirmed by the direct readings on the velocity–time graph.

A second example

The graphs below show a more extensive test of numerical integration.



Graph 3 – the model odometer records a more complex motion.

The probe rolled forward 90 cm at a velocity that approached 1 m/s at 2 seconds. It was brought to rest at 2.5 seconds and remained stationary until 4 seconds and was then returned to its original position in two stages, moving backwards from 4 to 5 seconds, being stationary again between 5 and 6 seconds, and then returning to its original position with a decreasing velocity.

The exact agreement to three figures between the direct measurement of total displacement (0.533 cm) and the velocity time integral (0.533 s.cm/s) is a consequence of reliable numerical integration.