**VelocityLab/Voyager:**
**Using VelocityLab with LEGO® Carts**

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*Introduction*

Carts constructed with the LEGO® Simple & Powered Machines Set are great for studying motion kinematics, as the resultant motion is fairly smooth, resulting in less noisy data. While you can use the range finder and *PocketLab app*, it has been found by the author that using Voyager and the *VelocityLab app* is less noisy as well. The problem that one immediately confronts when considering this approach, however, is that both the small wheels and the large wheels in the LEGO® set are too small for attaching Voyager.

*Gears to the rescue!!!*

Figure 1 contains two photos of a LEGO® cart constructed for the purpose of studying kinematics with Voyager and the VelocityLab app. The wheels shown in the figure are the larger 4.3 cm diameter wheels, but they could easily be replaced by the smaller 3 cm diameter wheels. The left photo shows the front of the cart with Voyager centered and attached with a removable mounting square. Two 24t (teeth) gears are used, providing a gear ratio of 1:1. Therefore, Voyager turns with the same angular speed as the wheels. The driver gear is on the front wheel axle. The driven (follower) gear is at right angles to the driver gear, providing the desired horizontal rotation of Voyager. When using the VelocityLab app, one enters the LEGO wheel diameters (4.3 cm or 3 cm) just as if Voyager were mounted to the wheels.
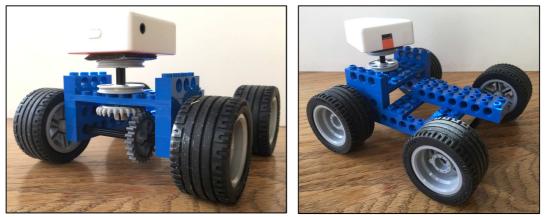


*Figure 1*

The photo on the right shows the rear of the cart. The blue bumper provides an object on the cart that can be given a quick impulse to get the cart in motion. A VelocityLab video of this cart in action accompanies this lesson. Figure 2 is an Excel chart constructed from the VelocityLab *csf* file.
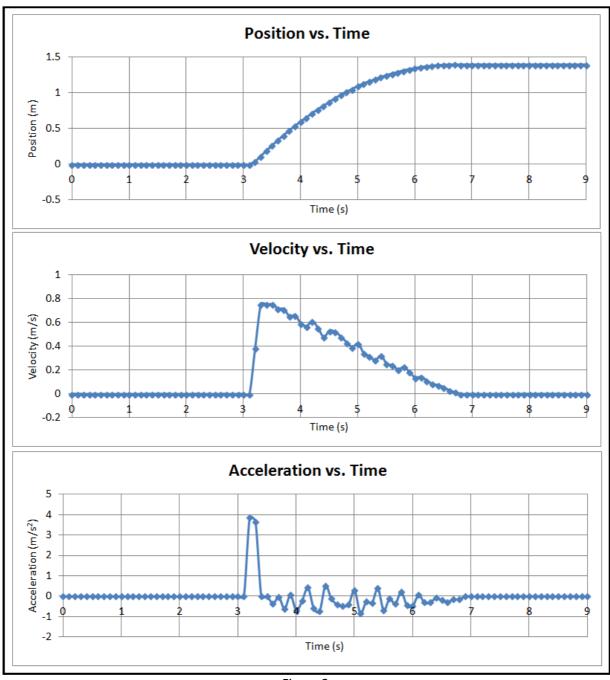
*Figure 2*

The velocity and acceleration graphs show that the initial impulse lasted for about 0.2 seconds, from 3.1 to 3.3 s. The cart is decelerating under (non-conservative) frictional forces from about 3.2 to 6.8 s. The position vs. time graph during this interval is parabolic. Therefore, a quadratic fit ($y = At^2 + Bt + C$) to this region could be used to obtain the acceleration, $d^2y/dt^2 = 2A$. Alternatively, the acceleration could be determined by performing a linear fit on the velocity graph and finding the slope. Finally, the acceleration could be determined by averaging the acceleration values over this region on the acceleration graph.