

Theoretical Calculation/Simulation

The cart's theoretical maximum acceleration was calculated using the mechanical properties of the 8020 aluminum bar. Due to base friction, the vertical bar is expected to tip before sliding. Figure 1 shows the forces acting on the bar.

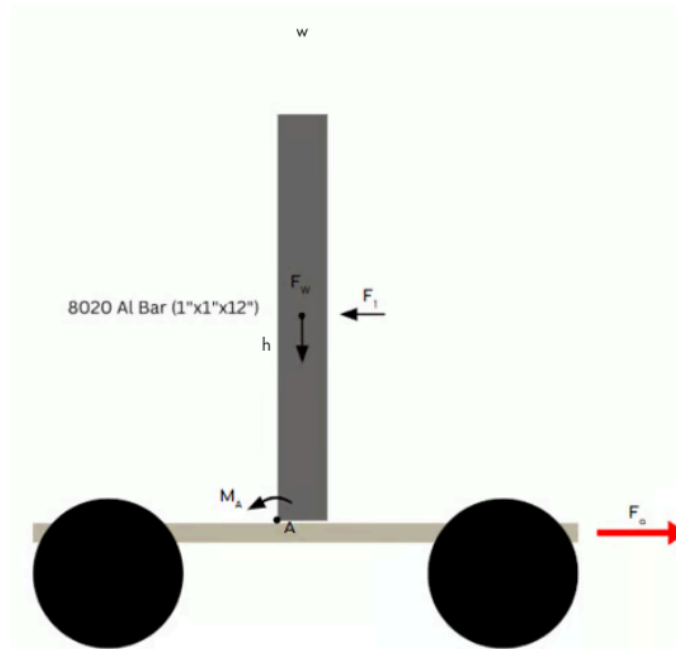


Figure 1: F_w is the resultant force of the weight of the bar. F_I is the inertial force acting on the bar, equivalent to F_a (the force of our acceleration). M_A is the sum of the moments about point A.

From the force diagram, we can solve for the cart's theoretical maximum acceleration. Deriving from Newton's second law, the equations for analysis are shown below:

$$\begin{aligned}
 F_I &= ma \\
 \sum M_A &= 0 \\
 \frac{F_I h}{2} &= \frac{F_W w}{2} \\
 ma_t h &= F_W w = mgw \\
 a_t &= g \frac{w}{h}
 \end{aligned}$$

And now our calculations with the given parameters:

$$a_t = (9.81 \text{ m/s}^2) \left(\frac{0.0254 \text{ m}}{0.3048 \text{ m}} \right) = 0.8175 \text{ m/s}^2$$

We then experiment with SolidWorks' Motion Analysis to discover the acceleration at which the net moment about point A is zero, found to be 0.8125 m/s^2 . See the figures below for the simulation setup and mating conditions used to constrain the bar to the correct degrees of freedom.

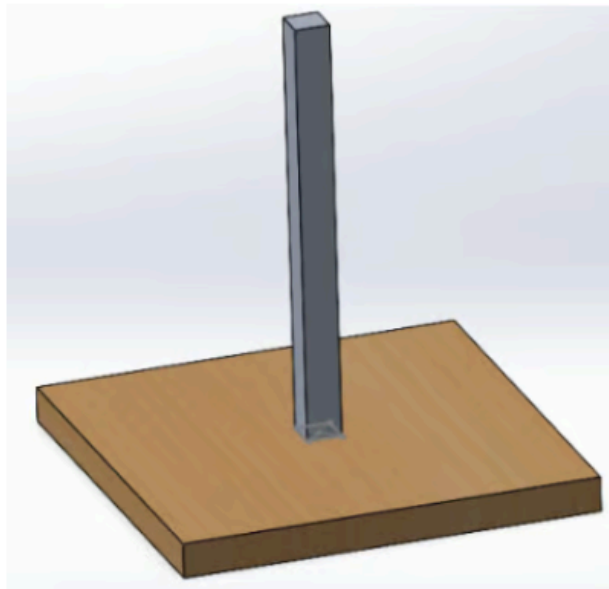


Figure 2: Platform mated to flat surface.

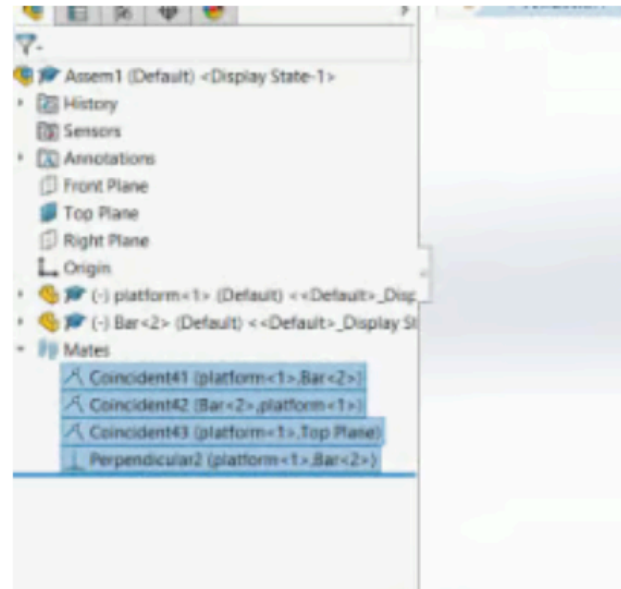


Figure 3: Mates shown.

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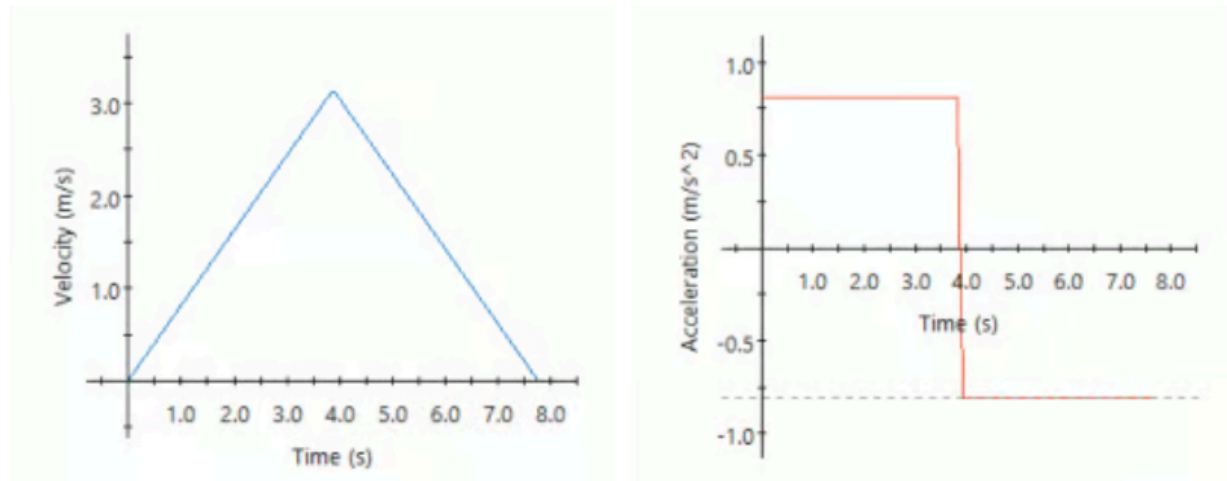


Figure 4: Velocity & acceleration profiles for the platform as a function of time, with no bar tipping observed.

From the maximum velocity, the optimal wheel radius was calculated. At the highest PWM, the DC motor reached a maximum of 320 RPM. See the calculation below:

$$r = \frac{v}{\omega} = \frac{3.15 \text{ m/s}}{33.51 \text{ rad/s}} \approx 0.094 \text{ m} \approx 3.7 \text{ in}$$

During construction, the initially-considered 3.7 in. radius was deemed unnecessary. The single DC motor likely lacked sufficient torque to drive wheels of that size effectively. Reducing the wheel size to a 2.5 in. radius also effectively minimizes the printing window. Below, the angular velocity profiles are shown.

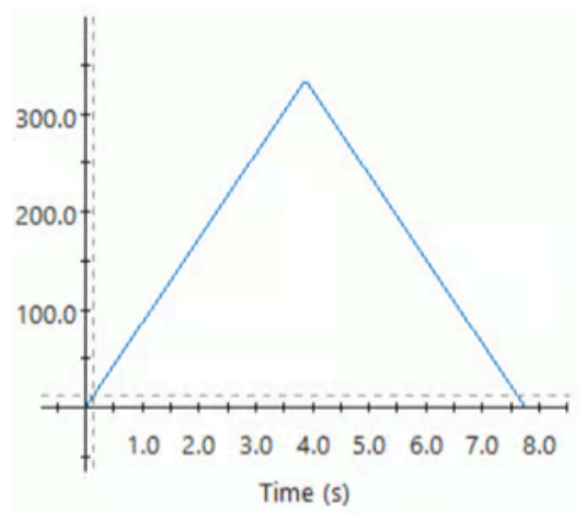


Figure 5: Maximum angular velocity profile. Maximum angular velocity is equal to 320 RPM. (Note: y-axis is in RPM)

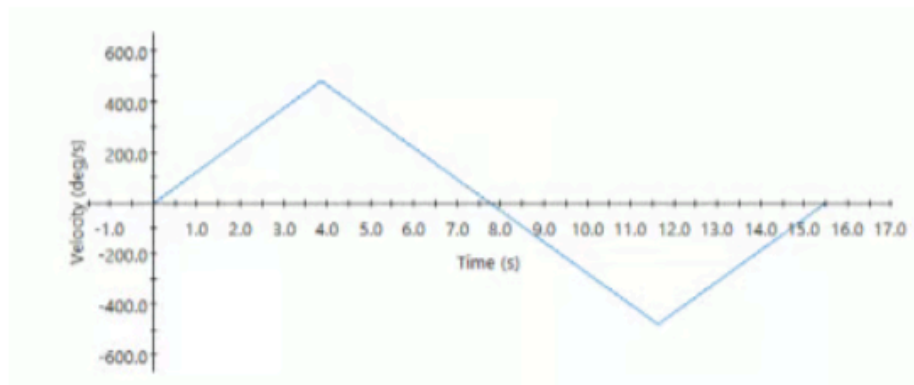


Figure 6: Practical angular velocity profile to be modeled by cart's Arduino.