Design and Construction of a Small Solar-Powered Vehicle

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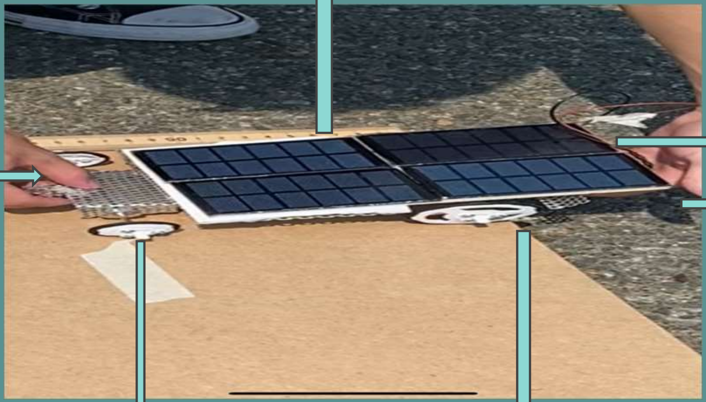
Project Goals

- **Build a functional solar powered car from given materials**
- **Use MATLAB and mathematical reasoning to calculate optimal gear ratios and wheel diameters to minimize time**
- **Conduct tests to verify properties of car**
  - **No load current**
  - **Static torque**
  - **Efficiency**
- **Minimize the time taken for the car to reach the end of the track of any given size**

The Car Design Process

Styrofoam was used to slightly slant the solar panel towards our predicted location of the sun in order to intake as much sunlight as possible

A unique bent in tip (triangle) to minimize air resistance.



Assemble a frame with the least amount of mass but just enough to have a unique design that considers minimizing air resistance.

A resulting frame with a bent-upwards frame in order to stabilize the solar panel and give room to fit in circuitry.

Front tires attached by bending by bending two flaps downwards.

Front wheels deliberately smaller than back wheels in order to increase the angle of the slant to absorb as much sunlight as possible.

Operating Instructions

Track Length (m)	Wheel Diameter (m)	Gear Ratio	Current Available (A)
0.5	0.070	47.5	0.2
1	.0550	22.6	0.2
1.5	.0550	22.6	0.2
2	.0360	10.8	0.2
2.5	.0360	10.8	0.2
3	.0360	10.8	0.2
3.5	.0360	10.8	0.2
4	.0360	10.8	0.2
4.5	.0360	10.8	0.2

Table of optimal gear ratios and wheel diameters

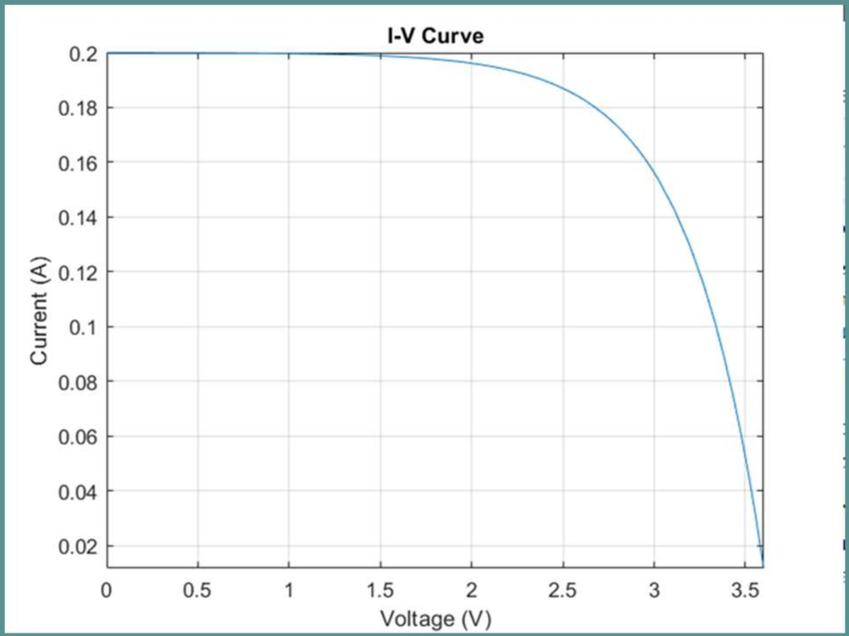
Design Specifications

- **Total weight of the vehicle: 180 grams or 0.180 kg**
- **Transmission ratio: 10.8:1**
- **Expected performance: 0.9 m/s**

Design Calculations

I. Determining the values of $\{R,\beta,T_o,\tau_o\}$
   A. Using a MATLAB's built in system of equations solving tool, we developed equations and solved for these certain values.
   B. $\{R,\beta,T_o,\tau_o\}$ = {5.0 Ω, 3.07e-3, 8.17e-5 Nm, 1.17e-7 Nm}

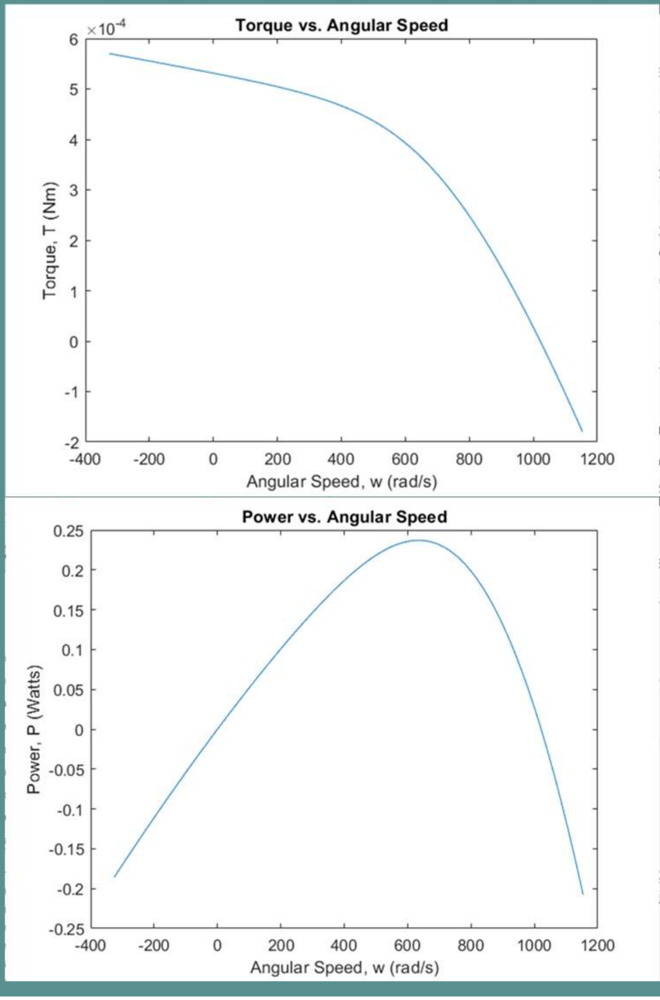
II. Determining the Solar Panel Properties, I_o and n
   A. I=I0-I1(exp(qv/nkT-)1) (Panel Equation)
   B. Using given constant values and preliminary I_o = 0.2 A and n = 16, we graphed I-V Curve



Design Calculations (cont’d)

III. Plotting the Torque and Power Curves against time
   A. $\omega = (V-IR)/\beta$ (Motor Equation 1)
   B. $T = \beta I - T0 - \tau 0\omega$ (Motor Equation 2)
   C. Using substitutions between these two equations and the Panel Equation, we derived a formula for T that we could plot parametrically
   D. $P = T\omega$, so using this we plotted P as well

IV. Given the following equations, we related motor speed to car speed:
   A. ω axle = +v/R where R is the radius of the wheel
   B. $\rho = \omega_{motor}/\omega_{axle}$
   C. We receive: $\boldsymbol{\omega_{motor} = 2\rho v/D}$



Design Calculations (cont'd)

V. Setting up the Equations of Motion in MATLAB to find time of path
   A. Here is the MATLAB script that was used to set up the ODE solver.
   B. We first used fzero to solve for I in our substituted Panel Equation
   C. The Differential Equation is set up below with the transmission value substituted in the motor speed.
   D. We set up our event function that will stop the curve at a point in time where the displacement of the car equals the track's length.

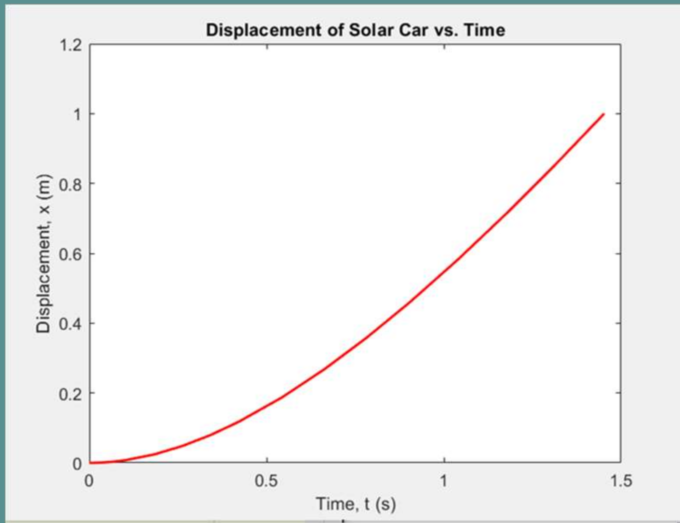
```
function z = f(II,I0,I1,n,k,T,q,R,beta,w_m)
z = I0 - II - I1*(exp(q*(4*II*R+beta*w_m)/(n*k*T))-1);
end

function [eventvalue,stopthecalc,eventdirection] = event(t,w,L)
x = w(1);
eventvalue = L-x;
stopthecalc = 1;
eventdirection = 0;
end

function dwdt = diffeq(t,w,m,eta,Cr,Cd,tau0,I0,I1,R,n,k,T,q,beta,T0,r)
x = w(1);
v = w(2);

w_m = r*v;
% r = (2*rho)/D
current = fzero(@(II) f(II,I0,I1,n,k,T,q,R,beta,w_m),0.2);
Tm = beta*(4*current) - T0 - tau0*w_m;

if (Tm < 0)
    Tm = 0;
end

dxdt = v;
dvdt = (1/m)*((eta*Tm*(r)) - Cr - Cd*v);

dwdt = [dxdt;dvdt];
end
```

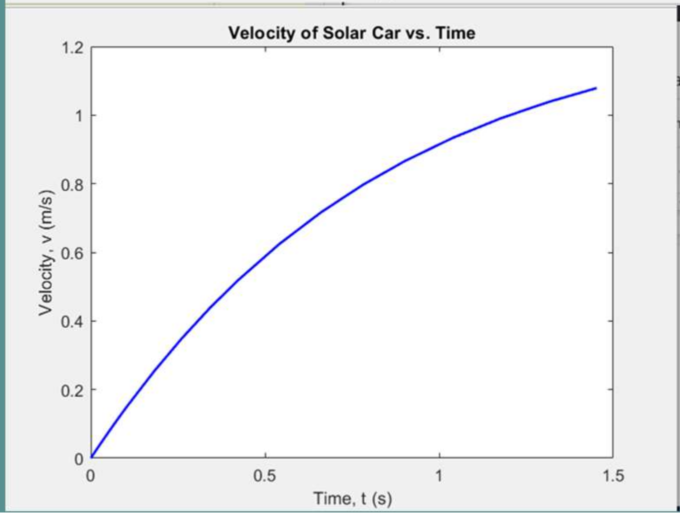
Design Calculations (cont’d)

VI. Solving the ODE and plotting the solar car’s path and velocity. Calculating the optimal transmission ratio.

   A. The graphs are describe the motion of the Solar Car

   B. By plotting the possible transmission ratios against the time travelled, we graphically analyzed a minimum point to determine optimal ratio.



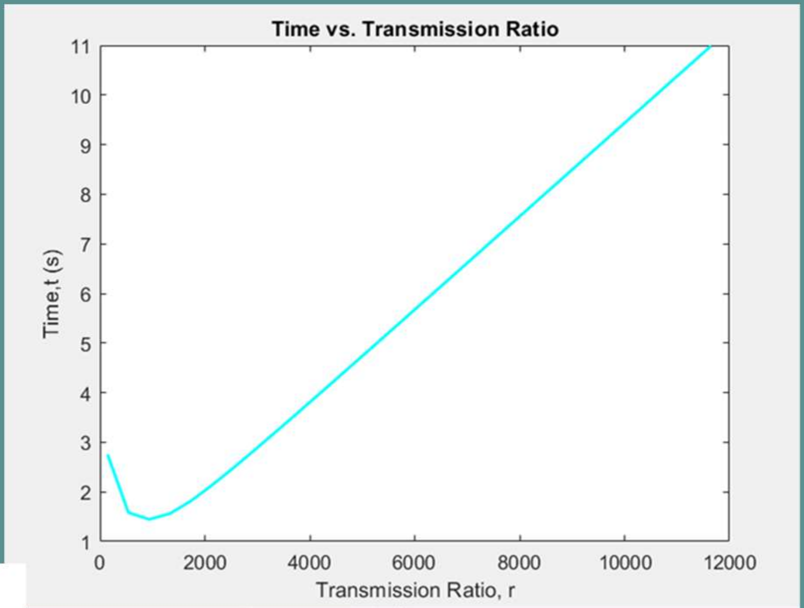


Design Calculations (cont'd)

VI. Here is the graph we used to determine the optimal transmission ratio.

A. The next step is to look at the matrix of possible values and select the closest value.

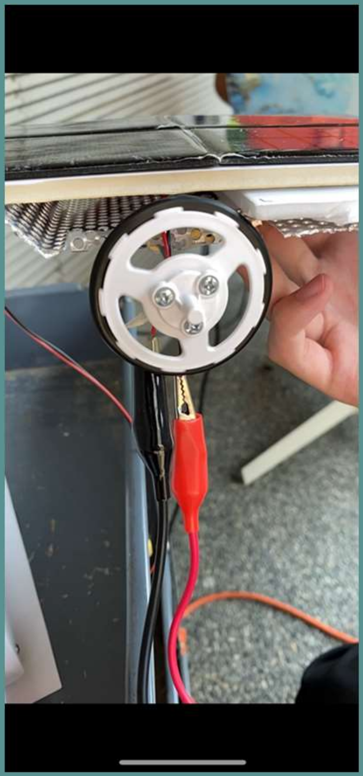
B. Each value on the matrix corresponds to a gear ratio and a wheel diameter.



283.33	185.45	170	145.71	127.5
600	392.73	360	308.57	270
1255.6	821.82	753.33	645.71	565
2638.9	1727.3	1583.3	1357.1	1187.5
5544.4	3629.1	3326.7	2851.4	2495
11650	7625.5	6990	5991.4	5242.5

Testing and Experiments

- **To measure different properties of the car, we conducted real-life tests to determine if the car was adequately functional for the day of the race**
  - **Test 1: Motor speed**
  - **Test 2: Static friction torque**
  - **Test 3: Stall current**
  - **Test 4: Efficiency**



Test 1: Counting the number of Revolutions of the wheel at .75 W

Challenges

- The first challenged we faced was that the MATLAB design problems were syntactically tough.
- In MATLAB, it was hard to keep track of the many variables given. This was also a big challenge.
- Another challenge we faced was that the front axle of the car wasn't stable and kept rotating at first.

Conclusion and learning outcomes

- Good learning experience for hands-on building and testing
- Successful at using different design elements (i.e. MATLAB, physics, and real-life engineering) to put together the best possible product