Summary Comments

Background Information

The goal was to build a solar-powered mini-car using solar cells that were provided as well as choosing from gears and wheels from a kit that was also provided to each team.

The Scoring function was chosen to be:

$$Score = \frac{Dist * Mass}{Time}$$

where, Dist is the distance was measured in feet, Time was measured in seconds, and Mass was measured in grams. No particular "finish line" had to be crossed so velocity was used as a comparison for different distances covered.

The "race" was run on the sunny part of the long sidewalk near the sculpture by the SERC building entrance. The measurements were made on November 3, between 12:00 noon and 1:20 local time. This determined the sun angle and some teams used this information to guide their construction and design. The sky was clear, but the weather was windy, so this caused some extra randomness in the data.

Each team was instructed to measure their car with several different weight values to try and reach some kind of "optimum" value for their score – and to investigate some of the torque characteristics of the motor for the particular wiring arrangement that they chose for their solar cells.

Results

The raw data from the race is given in this table – and the best performance values for each team are written in the bigger font:

Team	time (s)	weight (g)	dist (ft)	score
1	15.2	72.0	34.00	160.9
1	15.3	100.0	34.00	222.5
1	13.1	156.0	23.00	273.5
1	12.0	212.0	18.25	**322.4**
2	3.4	110.0	17.42	**568.5**
2	3.0	110.0	14.00	518.5
2	7.0	220.0	16.50	518.6
2	10.0	334.0	10.00	334.0
3	6.3	92.0	20.25	296.7
3	6.8	120.0	20.75	**365.1**
3	1.0	232.0	0.00	0.0
3	16.0	176.0	18.08	198.9
4	9.9	25.8	16.25	42.5
4	4.9	118.0	12.83	308.4
4	7.3	148.0	19.00	384.7
4	9.5	202.0	21.33	**453.6**
4	19.5	398.0	13.25	270.4

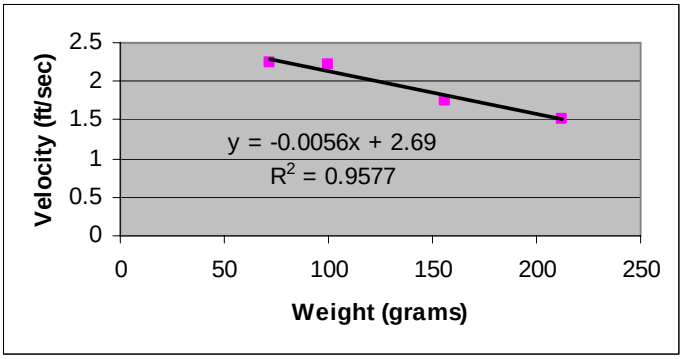
Analysis

Adding weight to the cars slowed them down – as would be expected. The extra friction exerted on the wheels required a

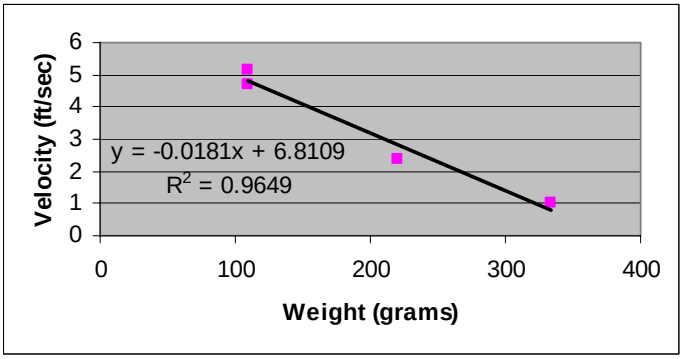
greater force to move the car at any given velocity. Note that the motion of the car laterally was not formally storing any of the solar power into mechanical potential energy. Rather the motor was fighting friction by pushing the car forward – and friction rose with increasing weight.

So, each team's velocity vs. mass response is shown in the following figures.

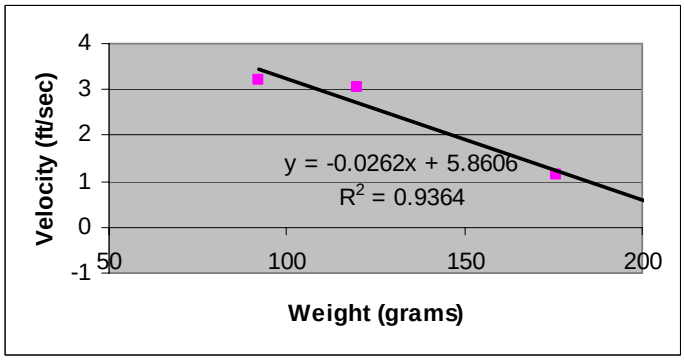
Team 1:



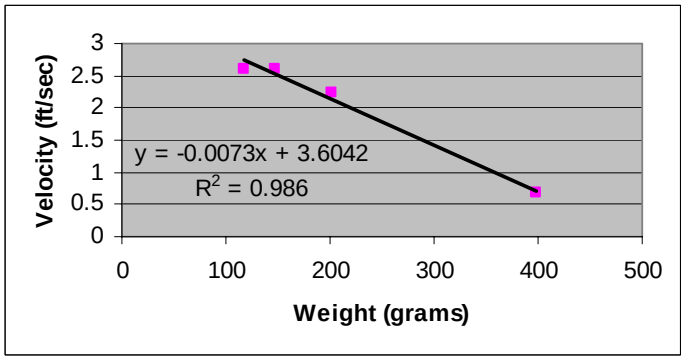
Team 2:



Team 3:



Team 4:



(neglecting one especially poor low-velocity outlier data point.)

Then, since (Velocity*Weight) was the scoring function, it was possible to estimate the possible maximum score for each team's car using the linear fits to the data that were measured.

First we have:

$$Velocity = slope * M + intercept$$

Then score is just:

$$Score = slope * M^2 + intercept * M$$

and the PEAK score should occur for a mass value determined by taking the derivative of the score function and setting it to zero and solving. I get this value:

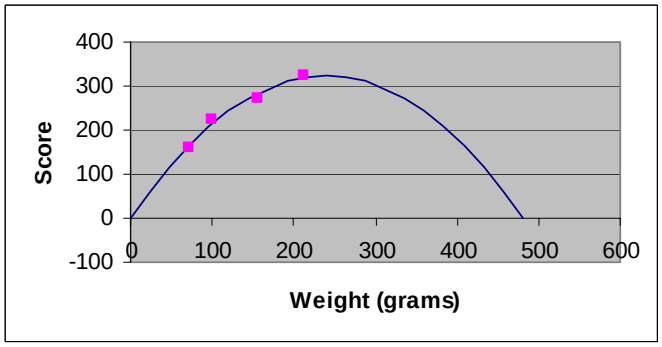
$$BestMass(estimate) = -\frac{intercept}{2 * slope}$$ And

using this mass value, the best-estimate of the peak score would be found as:

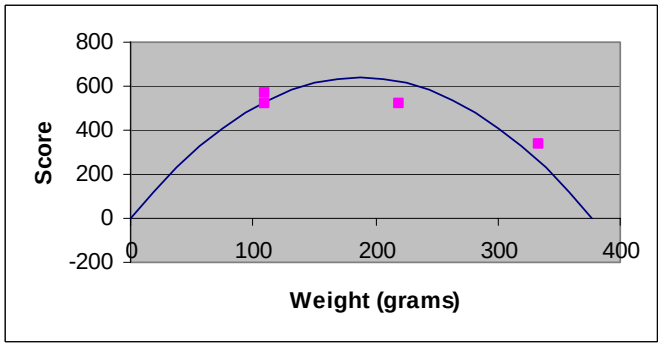
$$BestScore(estimate) = -\frac{intercept^2}{4 * slope}$$

The "ideal" fitted scoring function parabolas are plotted on the following four graphs – showing that each of the teams did quite a good job of getting close to their peak score value.

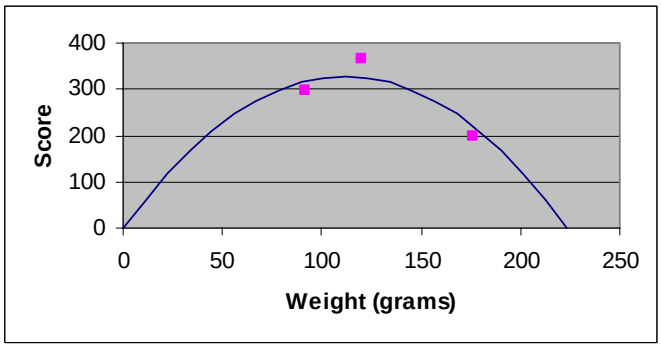
Team 1:



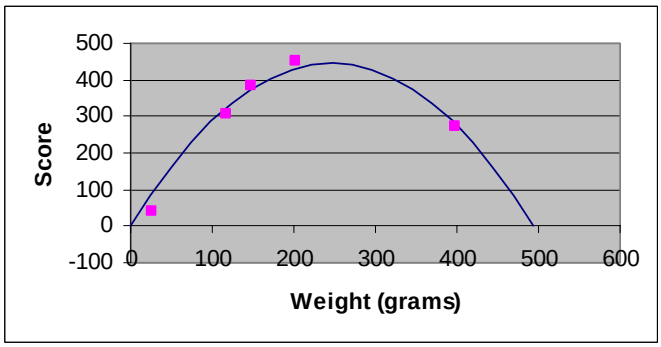
Team 2:



Team 3:



Team 4:



Discussion

Now it is interesting to question whether any of the design choices that you made were influential in giving you higher or lower peak score values.

Three factors might have impacted your scores: (1) the gear ratio used for your motor, (2) the wiring connections made to your cells, and (3) the use of sunlight in your design.

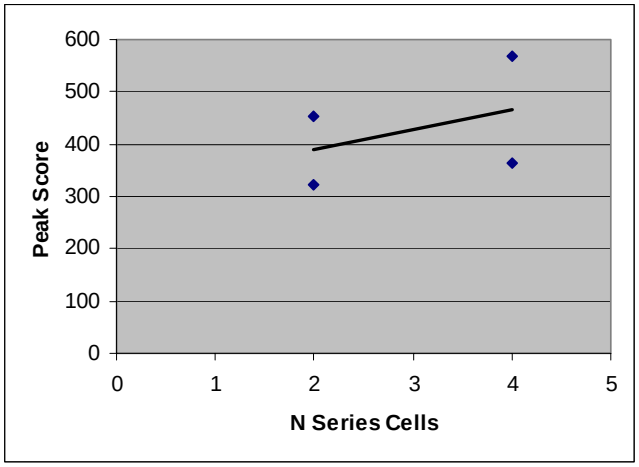
Here is how each team tackled these factors:

Team	Wiring	Gearing
1	2+2	1:6
2	4 Series	1:4
3	4 Series	1:1
4	2+2	1:3

Where "2+2" indicates that there were two strings in parallel of two cells in series.

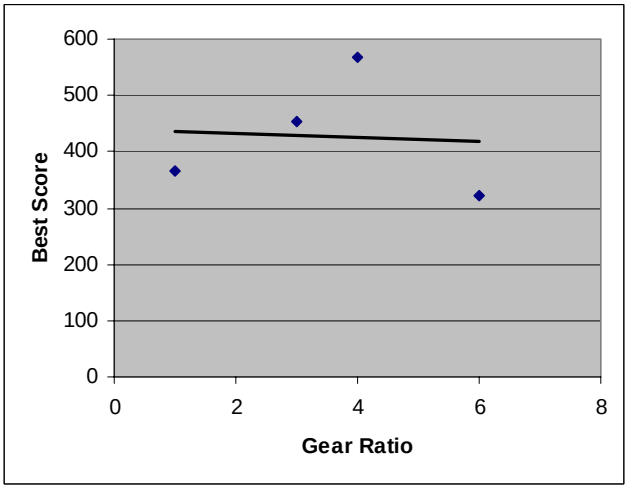
The wiring choice is essentially choosing a voltage vs. current tradeoff. The 2+2 should have half the voltage, but twice the current compared to the 4-in-Series configuration.

If we map peak performance against this choice then we get this plot:



This shows that it might be somewhat better to have 4 cells in series, though the scatter is high.

If we map peak performance against the gear ratio then we get this plot:



This shows no overall trend and plenty of scatter.

All four teams tilted their solar cells toward where the sun should be and one team (#4) added an aluminum foil reflector. In my examination of the reflector locations I'm not convinced that they got that much additional sunlight from their design, though future designs could definitely provide enhancement. I don't have any further comments on this point – but the reflectors would have to be at carefully designed angles to the sun for them to be effective.

Conclusions

As a practical matter, the same amount of sunlight was available for each of the teams. The choice of wiring will have an impact on the overall results because the motor has a particular current-voltage response and usually the DC motors

behavior is better at high RPMs and lower torque – so the higher gear ratios should be favored and the higher voltages should be favored. Only the latter correlation was demonstrated, but if both variables were fitted simultaneously (any takers in the class??), then we might be able to distinguish the effects of each parameter independently.