K&J Magnetics Mendocino Motor Worksheet

This report summarizes some theoretical work we did to answer these questions:
- What solar panels should we use?
- What gauge of magnet wire should we use?
- How many turns of wire should be used?

What follows is one solution for this problem. It isn't the only correct way to do it.
In fact, it might not be the greatest way.

Solar Panels

We chose solar panels from an electronics distributor called Futurlec.
We don't have any affiliation with them; we just found them online and the prices were great.

Note: There are 3 main kinds of solar cells:
- Monocrystalline
- Polycrystalline
- Amorphous

Learn more about these three types:
http://www.pvpanelguide.co.uk/guides/monocrystalline-polycrystalline-amorphous/
We figured we wantmonocrystalline or polycrystalline. Amorphous are inexpensive and not nearly as efficient.

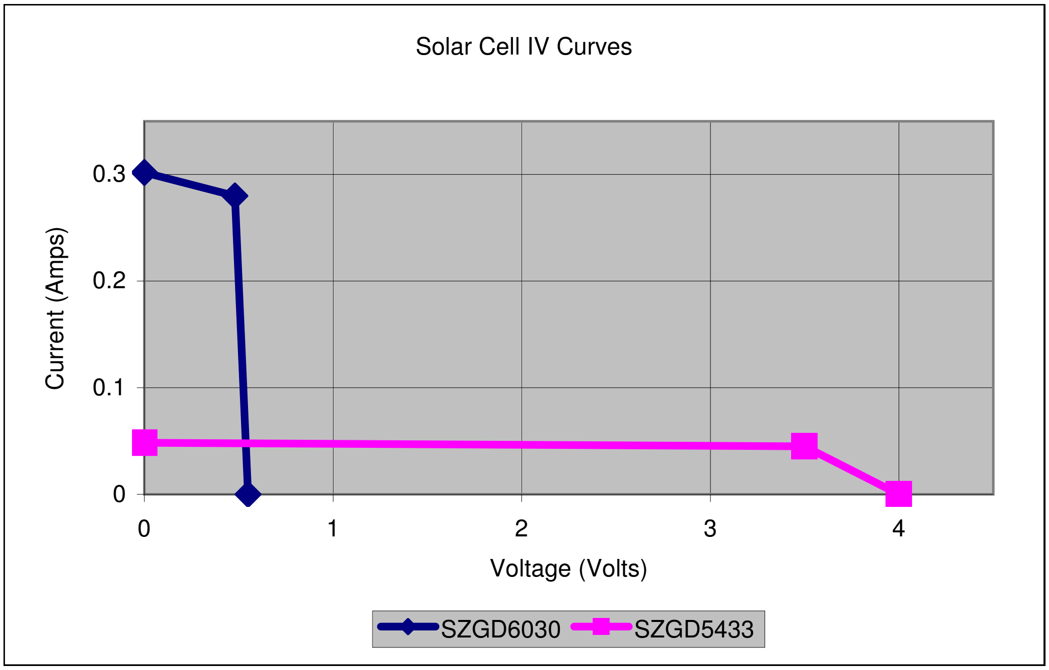
For a given panel size, there seems to be a choice. You can get them with specs that are:
- Higher voltage, lower current, or
- Lower voltage, higher current.

Which one is right for this motor? We compare two similar panels in this analysis.

PN:	**SZGD6030**		**SZGD5433**		
Vmp	0.48	V	3.5	V	peak voltage
Imp	0.28	A	0.045	A	peak current
Voc	0.55	V	4	V	open curcuit voltage
Isc	0.302	A	0.0485	A	short circuit current
Length	0.06	m	0.054	m	
	2.362	in	2.126	in	
Width	0.03	m	0.043	m	
	1.181	in	1.693	in	

What do these specs mean, Vmp and Imp? We found a great explanation at:
http://www.pveducation.org/pvcdrom/solar-cell-operation/short-circuit-current
The voltage and current you get out of a panel depends on the electrical resistance of the load placed on it.
The power you get out, where power = voltage * current (P=VI) also depends on this resistance.

These IV curves for the two panels are shown below.



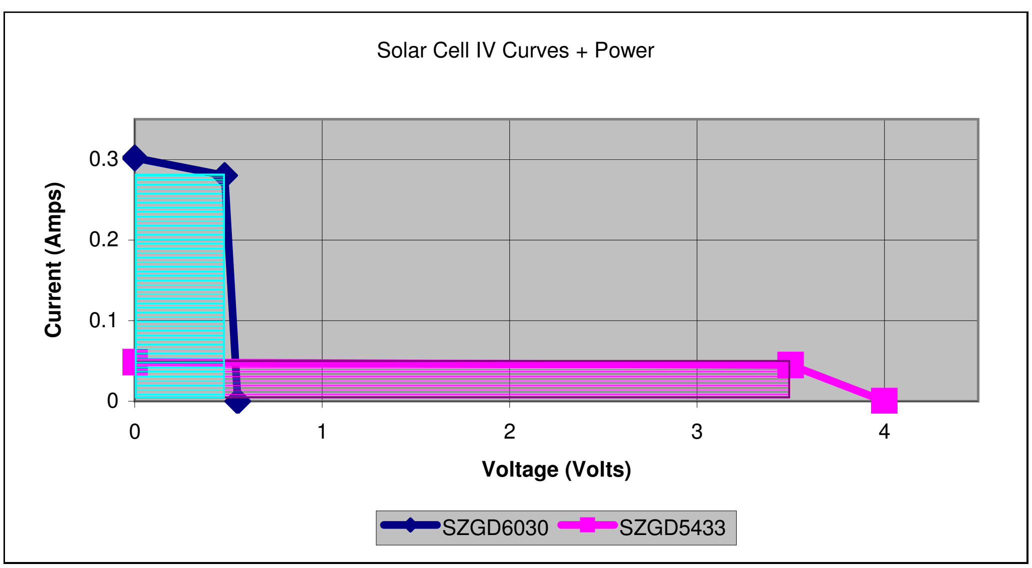
In either case, the point you want to operate at to get the most power is at the Imp, Vmp values.
To operate here, you choose the resistance (R = V / I) to be at that point.
This is called the characteristic resistance of a solar cell.

	SZGD6030	**SZGD5433**
Rch	1.71 Ohm	77.78 Ohm

If you put that much resistance across the panel, you'll get similar power output (P = V*I).

	0.302	**0.0485**
Power	0.13 W	0.16 W

Visually, the power is equal to the area inside that rectangle, shown below.



OK, that's all great information about solar panels, but we still don't know which will be better for our motor.
Let's keep considering the two, and think about running this electricity through our coil of wire sitting in a magnetic field.

Below is a list of several different gauges (diameters) of magnet wire,
with their lengths calculated to have the electrical resistance at the panel's characteristic resistance.

The list is organized by turns of wire, rather than the actual length.
With the design of this motor, we figured that one turn would be a bit larger than
the size of the panel dimensions:

Below is the length of the perimeter of loop of wire we figured, expressed in meters.

	SZGD6030		**SZGD5433**	
Loop L	0.2049	m	0.2296	m

How many turns is that to hit the characteristic resistance for the panel?

Gauge	**dia (in)**	**dia (mm)**	**R Ohm/m**	**SZGD6030 turns**	**SZGD5433 turns**
20	0.032	0.81	0.0333	251	10172
22	0.0253	0.64	0.053	158	6391
24	0.0201	0.51	0.0842	99	4023
26	0.0159	0.40	0.134	62	2528
28	0.0126	0.32	0.213	39	1590
30	0.01	0.25	0.339	25	999
32	0.00795	0.20	0.538	16	630
34	0.00631	0.16	0.856	10	396
36	0.005	0.13	1.36	6	249
38	0.00397	0.10	2.16	4	157
40	0.00314	0.08	3.44	2	98

For any gauge of wire, it looks like we can get the max power out of the panel with less wire using the low voltage panel. Still, how does this relate to the torque we'll see?

How do we calculate the torque (the force trying to rotate this motor)?
This powerpoint is a good reference.
http://highered.mcgraw-hill.com/sites/dl/free/007301267x/294295/Chapter30.ppt
From page 23, the maximum torque is: $T = N * I * B * A$, where

T	torque
N	number of turns
I	current (Amps)
B	magnetic field inside the coil (Tesla)
A	area of the coil (square meters)

To compare the two, I assumed an average magnetic field strength in the coil of:

67 gauss
0.0067 T

It's really stronger closer to the base magnet, and weaker farther away,
but this is a fair guess at a decent field strength.

Calculate torque for each panel, for different gauges of magnet wire:

	SZGD6030		SZGD5433	
I (Amps)	0.28		0.045	
B (Tesla)	0.0067		0.0067	
A (m^2)	0.0025456		0.0032838	
Gauge	N turns	Torque (N * mm)	N turns	Torque (N * mm)
20	251	1.20	10172	10.07
22	158	0.75	6391	6.33
24	99	0.47	4023	3.98
26	62	0.30	2528	2.50
28	39	0.19	1590	1.57
30	25	0.12	999	0.99
32	16	0.07	630	0.62
34	10	0.05	396	0.39
36	6	0.03	249	0.25
38	4	0.02	157	0.16
40	2	0.01	98	0.10

Wow! The higher voltage panel seems to supply a lot more torque.
We somewhat arbitrarily chose 30 gauge wire.
In our excitement for more strength, we ignored the fact that
one thousand turns of wire would be much heavier than 25 turns!

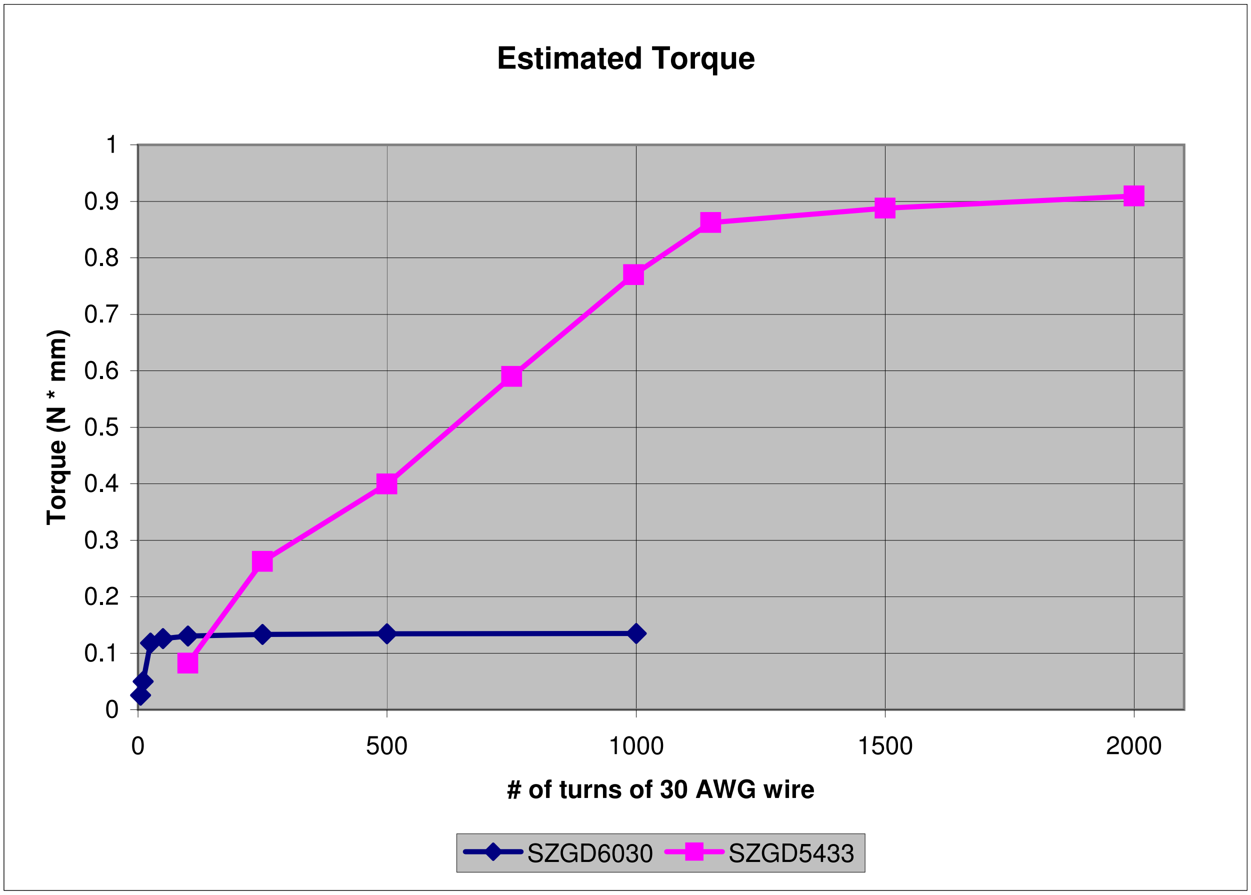
What is the estimated total length of the wire?

	SZGD6030	**SZGD5433**
Gauge	**length (ft)**	**length (ft)**
30	16.6	752.7

What is the estimated total weight of the wire?

	SZGD6030	**SZGD5433**
Gauge	**mass (lb)**	**mass (lb)**
30	0.01	0.23

Addendum #1:
What if we used a different number of turns of wire? What would the effect on torque be?



Less turns than the calculated optimum results in less torque.
More turns doesn't get any more torque.