5. TRANSMISSION

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The electric vehicle build programme for New Zealand schools!

Take up the challenge to use an electric bike kit to power an electric bike or cart of your own design, and outdo your friends on Race Day!

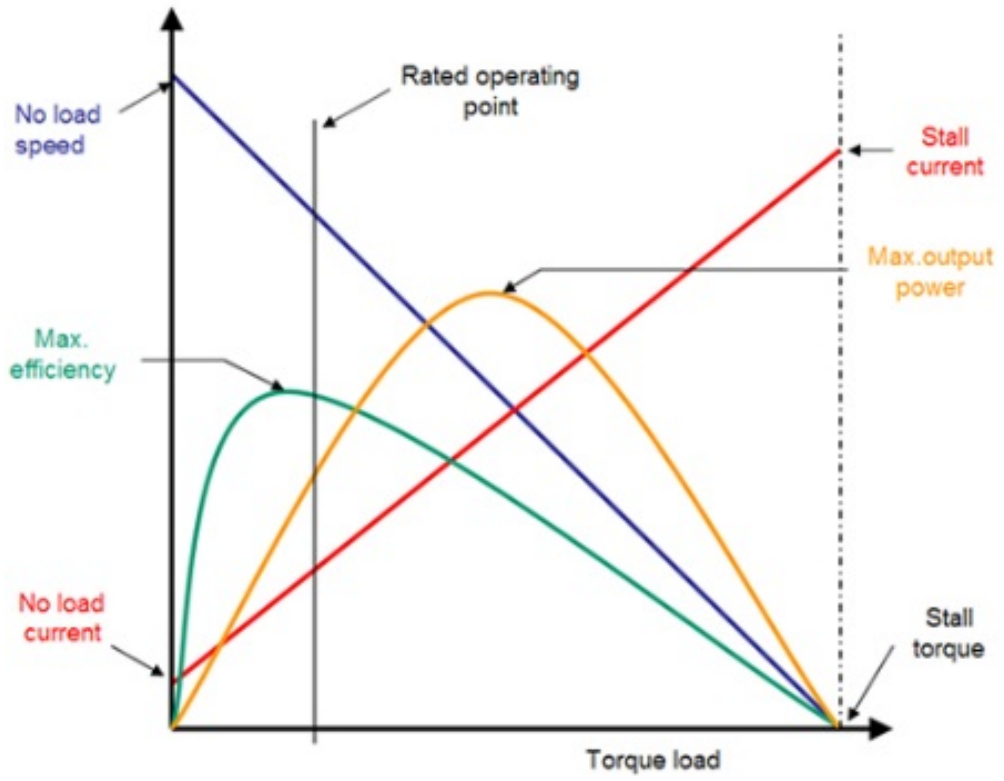
IS GEARING NEEDED?

When the motor is starting off very large currents rush from the battery through the copper wire windings in the motor. These have very low resistance at this stage and huge turning forces (Torque) are generated by the large current. As the motor begins to spin a type of resistance (impedance) builds up to reduce the current and therefor the size of the turning force. As the motor speed builds up the impedance grows and reduces the current size and torque.

In this way the motor starts with huge torque but plateaus after a while and speed will not increase. The trick is to use this low down torque several times by changing up to a higher gear and using the high torque again.

As can be seen from these curves:

Max Torque occurs when revs are zero
Max power occurs at approx. ___ % of max revs
Max efficiency occurs at approx. ___ % of max revs



We need to be able to use this information!

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IS GEARING NEEDED?

Standing on your pedals for max torque (low speed) in low gear

Speedy pedalling for max speed low torque in high gear.

This is not so different to when you turn the pedals on your bike.

Starting out, you stand on your pedals and produce large turning forces but once underway in a low gear you end up pedalling so fast you cant get the same pressure on the pedals and the speed ultimately stops growing.

The electric motor is exactly the same, but on most bikes you then fix the problem by switching up to a higher gear. This will allow you to slow down the pedalling stand on the pedals again to apply large torque and have the back wheel rotate faster (greater road speed). Starting off in this gear would be a lot harder.

In this way we need different gears to get underway to the ones we need for top speed.

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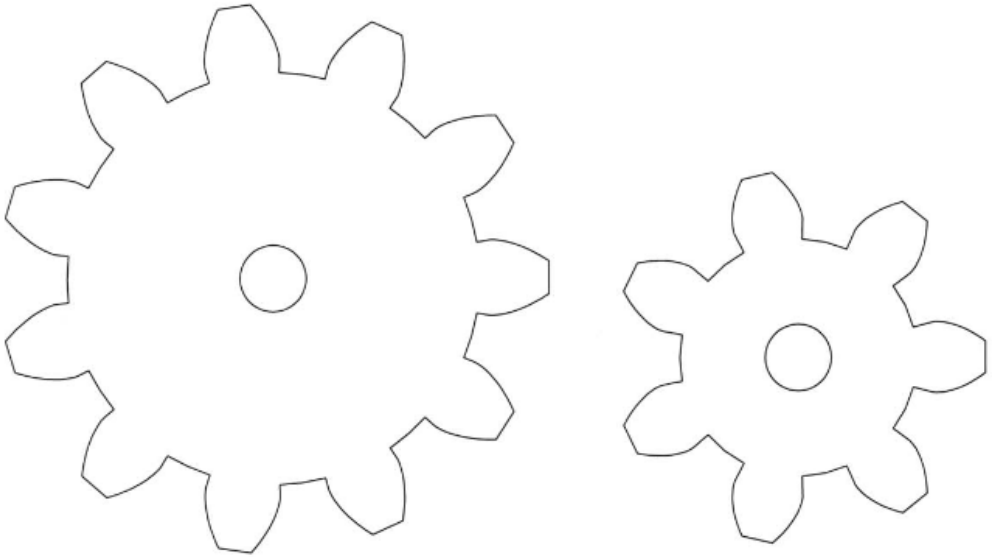
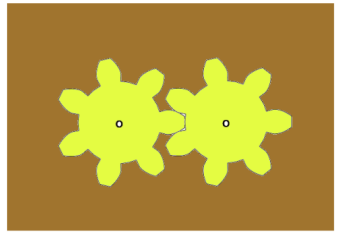
PLAYING WITH GEARS 1

1. Print 2 copies the gears on the right into stiff card
2. Cut them out and colour the small ones yellow, big ones blue
3. We will get them to mesh and put a drawing pin through their centre and into a stiff cardboard backing
4. Now let's see the difference between gear combinations.

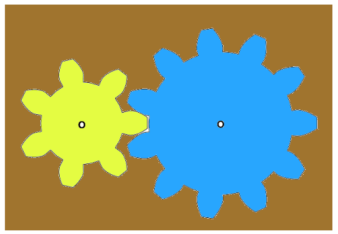


Driver gear **Driven gear**



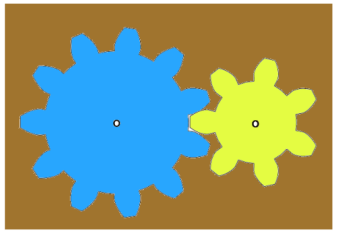
Turn the Driver gear one full turn. How much does the Driven gear turn?

Gear ratio = $\frac{\text{Driver turns}}{\text{Driven turns}}$ = $\frac{\text{Teeth on Driver}}{\text{Teeth on Driven}}$ = _____



Repeat the above

Gear ratio = $\frac{\text{Driver turns}}{\text{Driven turns}}$ = $\frac{\text{Teeth on Driver}}{\text{Teeth on Driven}}$ = _____



Repeat the above

Gear ratio = $\frac{\text{Driver turns}}{\text{Driven turns}}$ = $\frac{\text{Teeth on Driver}}{\text{Teeth on Driven}}$ = _____

Which gives the highest gearing Small to Large or Large to Small?

Which is the fast gearing _____

Which would you use for going slowly up hill? _____

Which gearing would you engage if you were pushing off from a standing start? _____

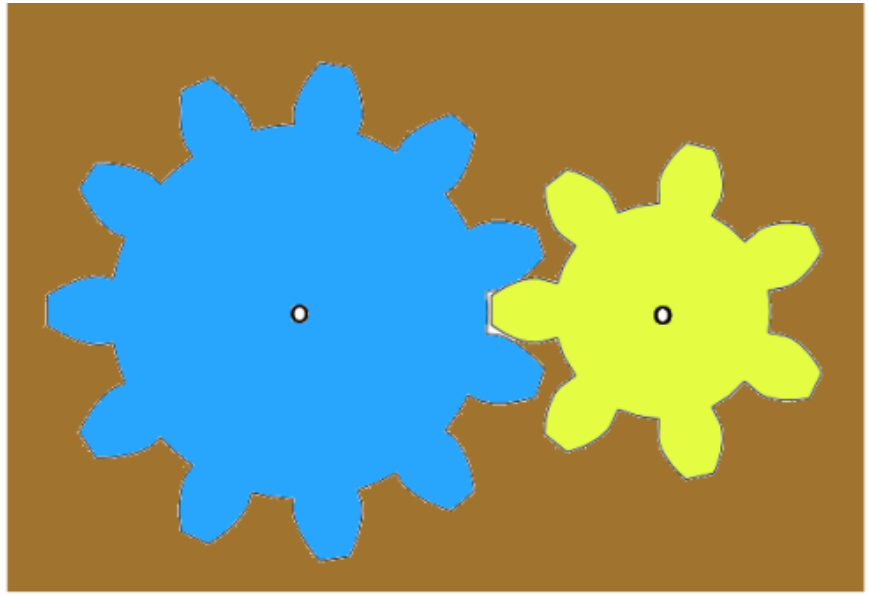
Why? _____

We will have ensure our motor can get the vehicle underway and then decide on which gearing we can use to get the highest speed.

While these are gears and not a sprocket and chain system like a bike it still has the same principles. When a link of the chain comes off the driver sprocket a link turns onto the driven sprocket. The big difference with a chain and sprockets though is both sprockets turn in the same direction.

PLAYING WITH GEARS 2

Driven Driver



Most gearing we will use will be like this. Most direct drives will be like this (amended diagram) where a small driver sprocket drives a larger rear sprocket.

If driving onto a pedal crank and using the bikes gearing a ratio of 1:1 for the motor and pedal crank driven sprocket will then allow the bike gears scope to perform well.

You will have to experiment with the gearing that will get your vehicle off the mark and the best gearing your motor can use to achieve max speed. Retaining the bikes gears is very useful in this experimentation.

Three build requirement that are absolutely critical are

1) Ensure your sprockets are accurately aligned – otherwise the chain could break.
2) Tension the chain to make sure it cannot jump teeth or jump off
3) Make sure the mount is very sturdy, otherwise its torque will break it off its mounts.as it gets the vehicle going. It is MUCH stronger than it looks

GEARING OPTIONS– DIRECT DRIVE SYSTEMS

Is this geared up or down?
How can you tell

With this gearing it will be set to either
Accelerate quickly

Or it could be set up for _____

This has a very large back sprocket. It looks to be very _____ geared.

It was entered in the Open class and must have a motor that with a *low / high* rev limit.

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GEARING OPTIONS– MULTIPLE STAGE TRANSMISSIONS

All of these systems use a two step chain drive to enable the gearing system of a bike to be used effectively. Usually this means the electric motor drives the pedal crank which them drives through the bike chain and gears to the back wheel.

Teams identify which gearing they need in order to optimise performance for each event.

The Drag Race needs the vehicle to get off the mark quickly and the transition through an intermediate gear to reach the high gear needed for highest speed

The stopping and starting of the **Gymkhana** requires a low gear and possibly one higher one

Good performance in the Economy Run requires the vehicle last as long as possible for the lowest energy draw from the battery.

Some variations of the motor driving the pedal crank and leaving the full bike gears available to take advantage of the high torque but quick rev out of this electric motor.

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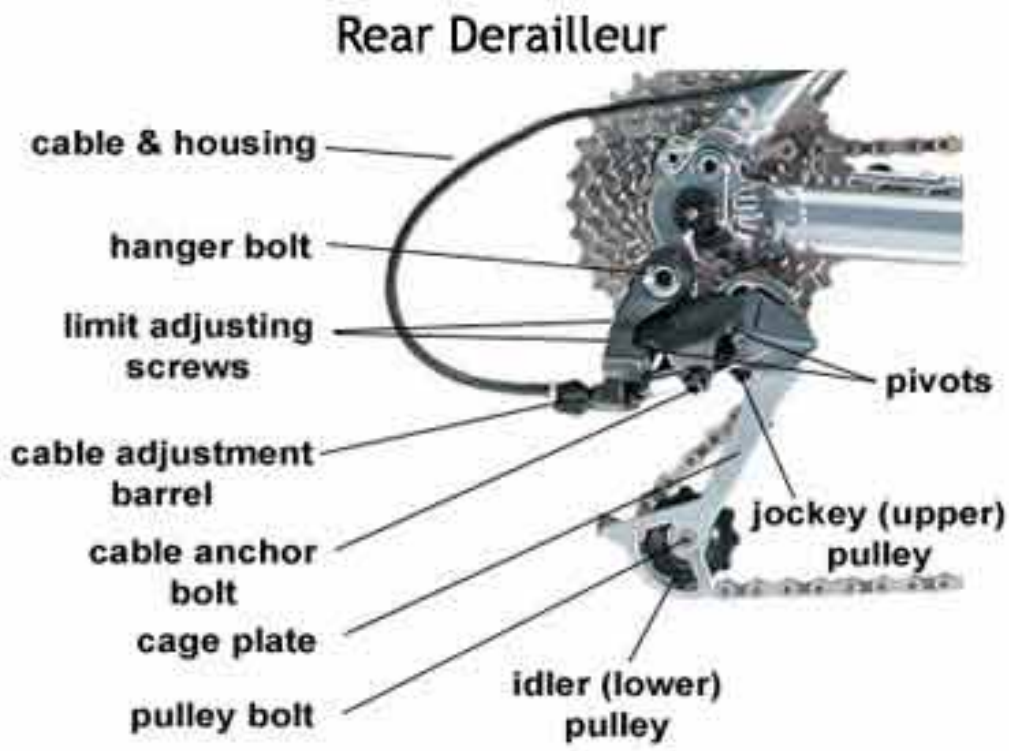
BIKE DERAILLEUR SYSTEM

A useful gearing and gear change mechanism that is appropriate for the Standard Kit motors.

At the back wheel of a geared bike. The derailleur system pushes or pulls the chain across to select smaller or larger sprockets and therefore changes the gearing.

A similar system often controls 3 sprockets on the front pedal cluster too. With 3 choices on the front and 7 on the back you can then achieve 21 gears.

This a useful video explanation of bike gearing systems *<https://www.youtube.com/watch?v=j82TeunzkWM>*



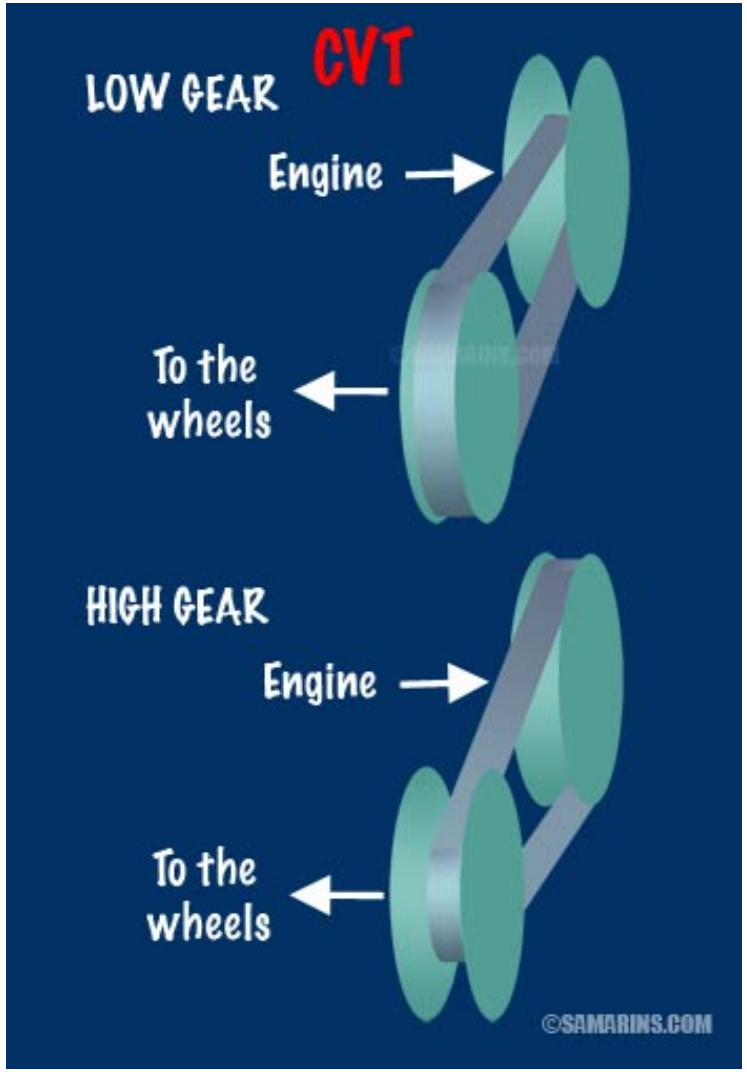
From <http://bikesonrobson.com/wp-content/uploads/2012/12/06-131-rear-derailleur.jpg>

CONTINUOUSLY VARIABLE TRANSMISSION (CVT)

This system supplies any gearing needed. A "V" belt is used between two vee pulleys much like a chain, BUT the separation of the sides of the pulleys can be altered.

As the sides of the drive pulley are separated, the belt moves down toward the centre of the pulley, connecting with it in a smaller circle.

At the same time the driven pulley squeezes in and the belt moves out to be driven by circle of larger diameter. The pulleys are adjusted continuously to keep the motor revving in its max torque range.



Waimea C used a CVT (Continuously Variable transmission) system in their vehicle in 2019. The system effectively gives them any gearing they need. Gearing can be connected to RPM to ensure it is always geared to always be working in the maximum torque range of the motor.

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SOME OPTIMISED GEARING OUTCOMES

Te Kopuku C designed their gearing well for the Street Circuit.

No need for much gearing in this Cambridge HS design!

Scots C had their gearing optimised in achieving 57kph!

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PERFORMANCE DATA FOR THE STANDARD 350W MOTOR

浙江尤奈特电机有限公司 电机测试报表

型号：MY1016-350W-24V 序列号：F20131230001 日期：2013年1月23日 操作者：

序号	T(N.m)	N(rpm)	Pout(W)	U(V)	I(A)	Pin(W)	η(%)
1	0.03	3454	10.85	24.05	2.07	49.78	21.79
2	0.04	3446	15.93	24.05	2.27	54.71	29.11
3	0.05	3438	20.98	24.05	2.48	59.64	35.19
4	0.07	3430	26.01	24.05	2.68	64.55	40.29
5	0.09	3422	31.02	24.05	2.89	69.49	44.64
6	0.10	3414	36.01	24.05	3.09	74.41	48.39
7	0.11	3406	40.97	24.05	3.30	79.34	51.64
8	0.13	3398	45.91	24.05	3.50	84.27	54.48
9	0.14	3390	50.82	24.05	3.71	89.19	56.98
10	0.16	3382	55.71	24.05	3.91	94.12	59.19
11	0.17	3375	60.58	24.05	4.12	99.05	61.16
12	0.19	3367	65.42	24.05	4.32	103.97	62.93
13	0.20	3359	70.25	24.05	4.53	108.90	64.51
14	0.21	3351	75.04	24.05	4.73	113.82	65.93
15	0.23	3343	79.82	24.05	4.94	118.75	67.22
16	0.24	3335	84.57	24.05	5.14	123.67	68.38
17	0.26	3327	89.30	24.05	5.35	128.60	69.44
18	0.27	3319	94.00	24.05	5.55	133.53	70.40
19	0.28	3311	98.68	24.05	5.76	138.45	71.28
20	0.30	3304	103.34	24.05	5.96	143.38	72.08
21	0.31	3296	107.97	24.05	6.17	148.30	72.81
22	0.33	3288	112.58	24.05	6.37	153.23	73.48
23	0.34	3280	117.17	24.05	6.58	158.15	74.09
24	0.36	3272	121.74	24.05	6.78	163.08	74.65
25	0.37	3264	126.28	24.05	6.99	168.01	75.16
26	0.39	3256	130.79	24.05	7.19	172.93	75.63
27	0.40	3248	135.29	24.05	7.40	177.86	76.07
28	0.41	3240	139.76	24.05	7.60	182.78	76.46
29	0.43	3233	144.21	24.05	7.81	187.71	76.83
30	0.44	3225	148.63	24.05	8.01	192.63	77.16
31	0.46	3217	153.03	24.05	8.22	197.56	77.46
32	0.47	3209	157.41	24.05	8.42	202.48	77.74
33	0.49	3201	161.76	24.05	8.63	207.41	77.99
34	0.50	3193	166.09	24.05	8.83	212.33	78.22
35	0.51	3185	170.40	24.05	9.03	217.26	78.43
36	0.52	3177	174.68	24.05	9.24	222.18	78.62
37	0.54	3169	178.94	24.05	9.44	227.11	78.79
38	0.55	3162	183.18	24.05	9.65	232.03	78.95
39	0.57	3154	187.40	24.05	9.85	236.96	79.08
40	0.58	3146	191.59	24.05	10.06	241.88	79.21
41	0.60	3138	195.78	24.05	10.26	246.81	79.31
42	0.61	3130	199.90	24.05	10.47	251.73	79.41
43	0.62	3122	204.02	24.05	10.67	256.66	79.49
44	0.64	3114	208.11	24.05	10.88	261.58	79.56
45	0.65	3106	212.19	24.05	11.08	266.50	79.62
46	0.67	3098	216.24	24.05	11.29	271.43	79.67
47	0.68	3091	220.26	24.05	11.49	276.35	79.70
48	0.69	3083	224.27	24.05	11.70	281.28	79.73
49	0.71	3075	228.25	24.05	11.90	286.20	79.75
50	0.72	3067	232.20	24.05	12.11	291.13	79.76

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序号	T(N.m)	N(rpm)	Pout(W)	U(V)	I(A)	Pin(W)	η(%)
51	0.74	3059	235.14	24.04	12.31	295.05	79.76
52	0.75	3051	240.05	24.04	12.52	300.98	79.76
53	0.77	3043	243.93	24.04	12.72	305.90	79.74
54	0.78	3035	247.80	24.04	12.93	310.82	79.72
55	0.79	3027	251.64	24.04	13.13	315.75	79.70
56	0.81	3020	255.45	24.04	13.34	320.67	79.66
57	0.82	3012	259.25	24.04	13.54	325.60	79.62
58	0.84	3004	263.02	24.04	13.75	330.52	79.58
59	0.85	2996	265.76	24.04	13.95	335.44	79.53
60	0.86	2988	270.49	24.04	14.16	340.37	79.47
61	0.88	2980	274.19	24.04	14.36	345.29	79.41
62	0.89	2972	277.86	24.04	14.57	350.22	79.34
63	0.91	2964	281.51	24.04	14.77	355.14	79.27
64	0.92	2956	285.14	24.04	14.98	360.06	79.19
65	0.94	2949	288.75	24.04	15.18	364.99	79.11
66	0.95	2941	292.33	24.04	15.39	369.91	79.03
67	0.96	2933	295.89	24.04	15.59	374.84	78.94
68	0.98	2925	299.43	24.04	15.79	379.76	78.85
69	0.99	2917	302.94	24.04	16.00	384.68	78.75
70	1.01	2909	305.43	24.04	16.20	389.61	78.65
71	1.02	2901	309.90	24.04	16.41	394.53	78.55
72	1.03	2893	313.34	24.04	16.61	399.45	78.44
73	1.05	2885	316.76	24.04	16.82	404.38	78.33
74	1.06	2878	320.16	24.04	17.02	409.30	78.22
75	1.08	2870	323.53	24.04	17.23	414.22	78.10
76	1.09	2862	326.88	24.04	17.43	419.15	77.99
77	1.10	2854	330.20	24.04	17.64	424.07	77.87
78	1.12	2846	333.51	24.04	17.84	428.99	77.74
79	1.13	2838	336.78	24.04	18.05	433.92	77.62
80	1.15	2830	340.04	24.04	18.25	438.84	77.49
81	1.16	2822	343.27	24.04	18.46	443.76	77.36
82	1.18	2814	346.48	24.04	18.66	448.69	77.22
83	1.19	2807	349.67	24.04	18.87	453.61	77.09
84	1.20	2799	352.83	24.04	19.07	458.53	76.95
85	1.22	2791	355.97	24.04	19.28	463.45	76.81
86	1.23	2783	359.08	24.04	19.48	468.38	76.67
87	1.25	2775	362.18	24.04	19.69	473.30	76.52
88	1.26	2767	365.25	24.04	19.89	478.22	76.38
89	1.27	2759	368.29	24.04	20.10	483.15	76.23
90	1.29	2751	371.31	24.04	20.30	488.07	76.08
91	1.30	2743	374.31	24.04	20.51	492.99	75.93
92	1.32	2736	377.29	24.04	20.71	497.91	75.77
93	1.33	2728	380.24	24.04	20.92	502.84	75.62
94	1.35	2720	383.17	24.04	21.12	507.76	75.46
95	1.36	2712	386.07	24.04	21.33	512.68	75.30
96	1.37	2704	388.96	24.04	21.53	517.60	75.15
97	1.39	2696	391.81	24.04	21.74	522.53	74.98
98	1.40	2688	394.65	24.04	21.94	527.45	74.82
99	1.42	2680	397.46	24.04	22.15	532.37	74.66
100	1.43	2672	400.25	24.04	22.35	537.29	74.49

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This data was supplied by the motor manufacturer

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