A
MOE University
Course

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The Miracle Workerz, FIRST Team 365

First State Robotics, Inc.
Wilmington, Delaware
www.moe365.org

Introduction to Motors*

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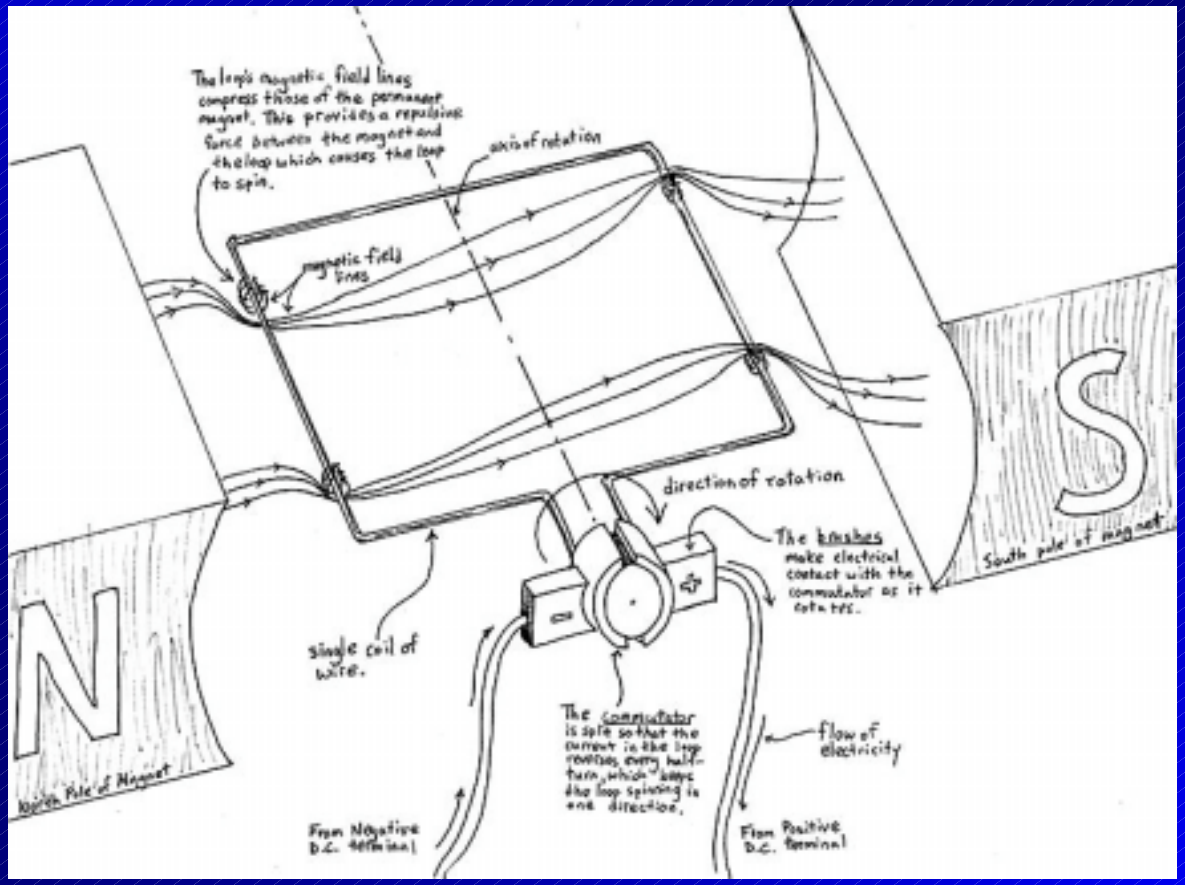
*Slides and Charts “borrowed” from Joe Johnson

Introduction to Motors

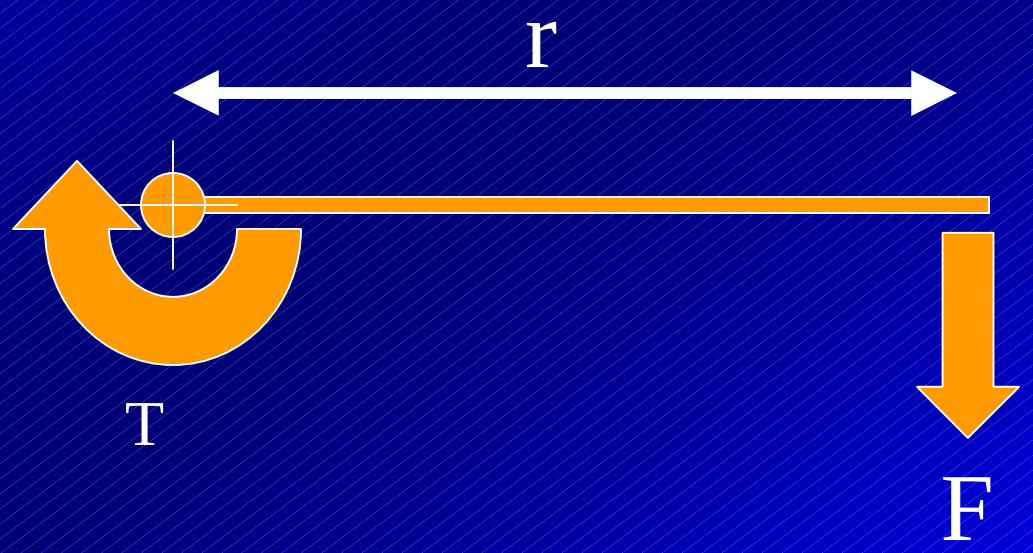
- How a DC Motor Works
- Motor Basics
- Motor Characteristics
- Kit motors
- Gearing
- How to use the motors
- GeroniMOE's Vital Statistics

How a DC Motor Works



Motor Basics - Torque

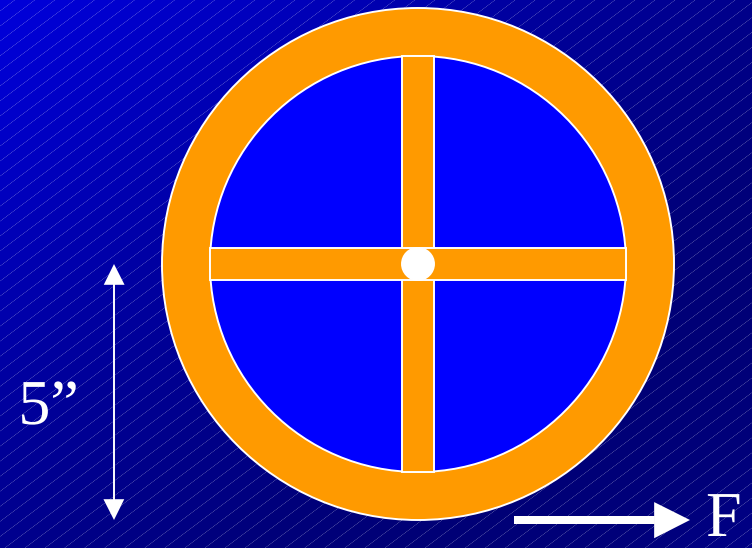
- Torque = force at the end of a handle
  - T (in-lbs) = F (lbs) x r (inches)



Motor Torque - example

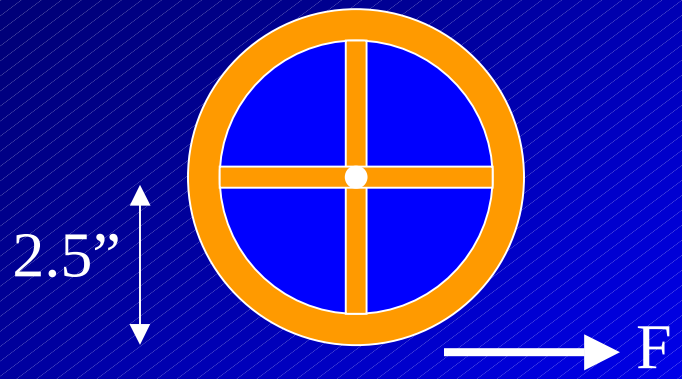
For the Bosch drill motor at the low setting T = 250 in-lbs

10 inch diameter wheel



250 in-lbs = F x 5 inches
F = 50 lbs

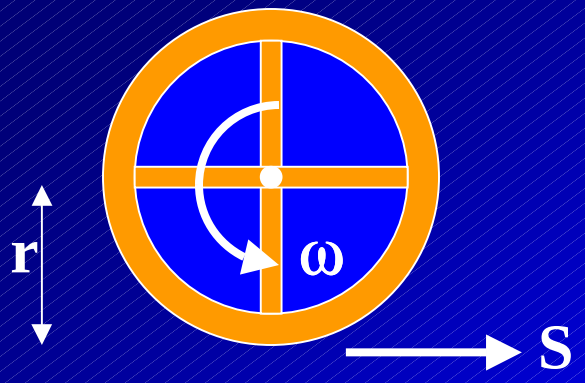
5 inch diameter wheel



250 in-lbs = F x 2.5 inches
F = 100 lbs

Motor basics - speed

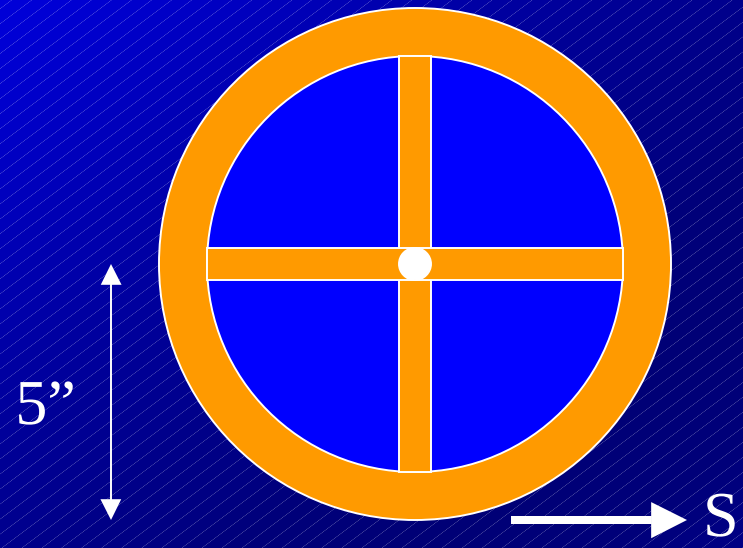
- Motor speed, ω, is measured in RPM (revolutions per minute)
- Ground speed,
  - S (in/min) = ω (rpm) x 2 x π x r (in)



Speed - example

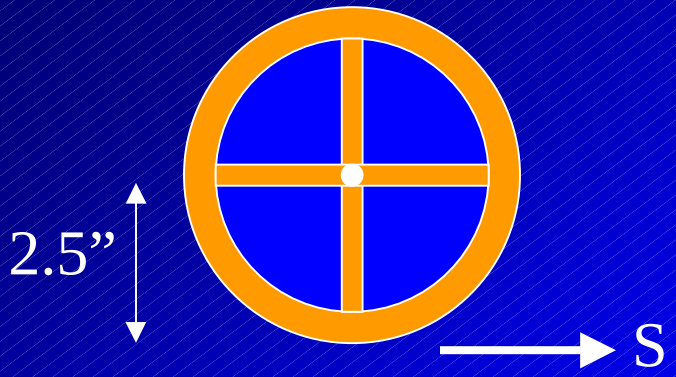
For the Bosch drill motor at the low setting ω = 300 rpm

10 inch diameter wheel



S = 300 rpm x 5” x 2 x π
S = 9400 inches/min
= 780 ft/min

5 inch diameter wheel

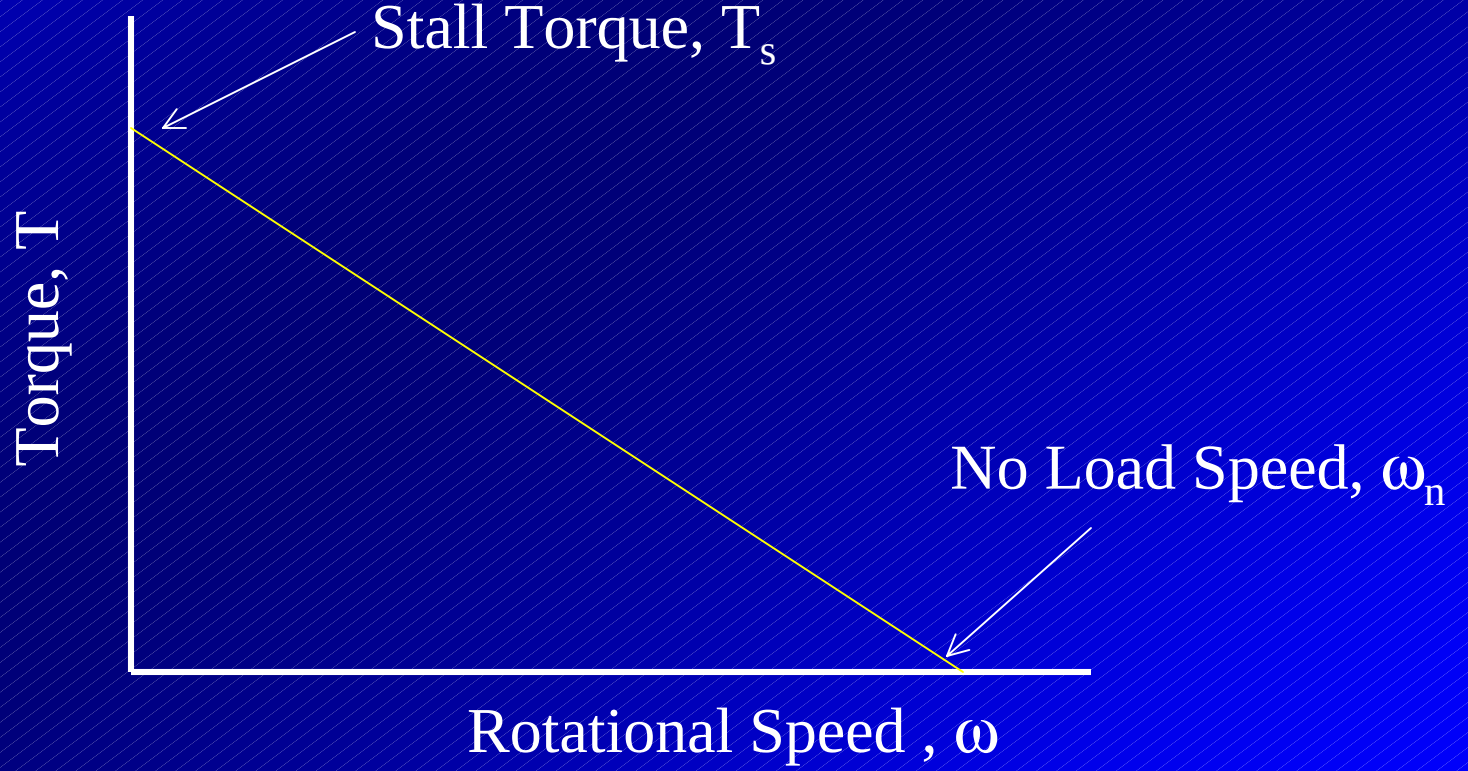


S = 300 rpm x 2.5” x 2 x π
S = 4700 inches/min
=390 ft/min

Motor basics - power

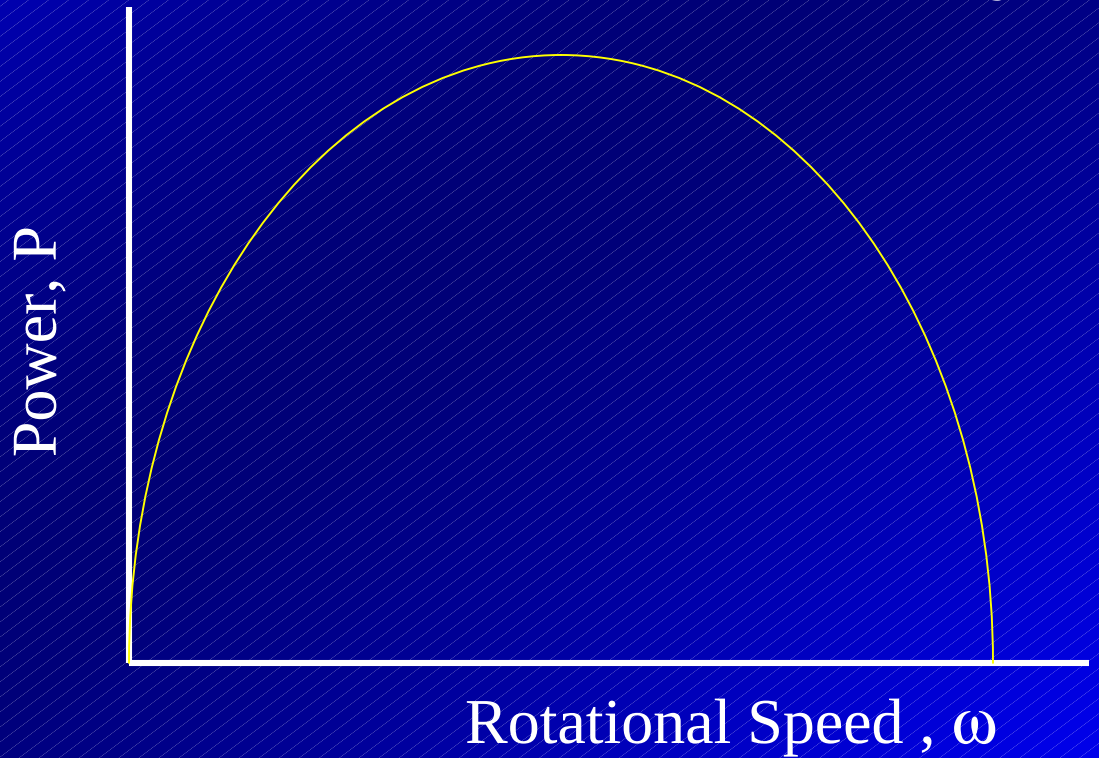
- Power is how fast work is done
- Power() = Force x speed
- For a motor, P = T (in-lbs) x ω (rpm)

Motor characteristics - Torque/speed curves



Motor characteristics - Power/Speed curves

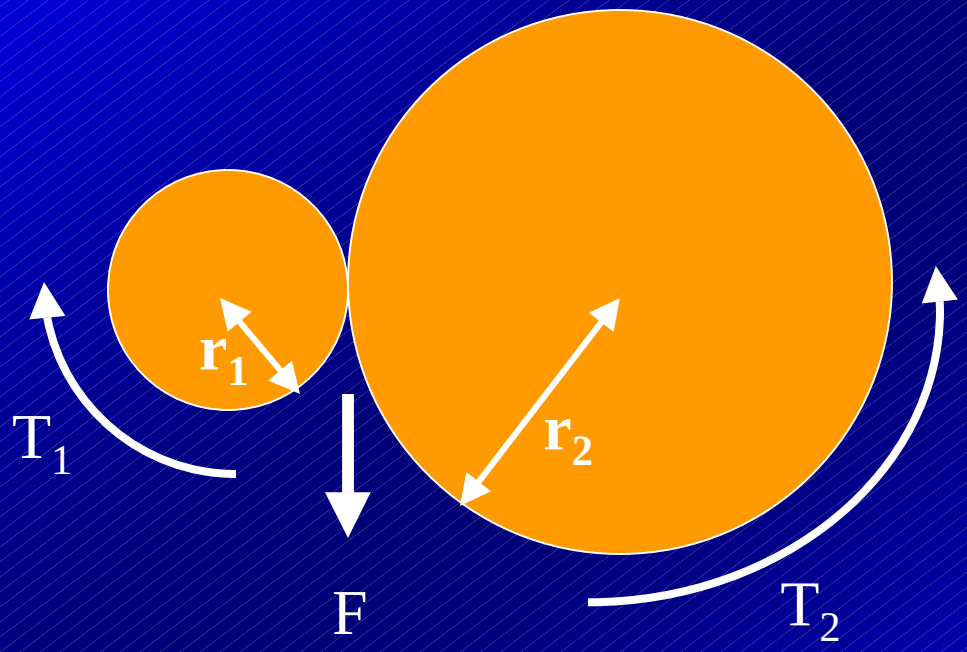
$$P = -(T_s / \omega_n)\, \omega^2 + T_s \times \omega$$



Gearing Basics

- The motors have too little torque and too much speed to be useful
- Must gear them down to get them to perform
- The Drill motor, F-P, and Globe come with their own gearboxes
- Most common types
  - Spur
  - planetary
  - chain

Gearing Basics - spur gears

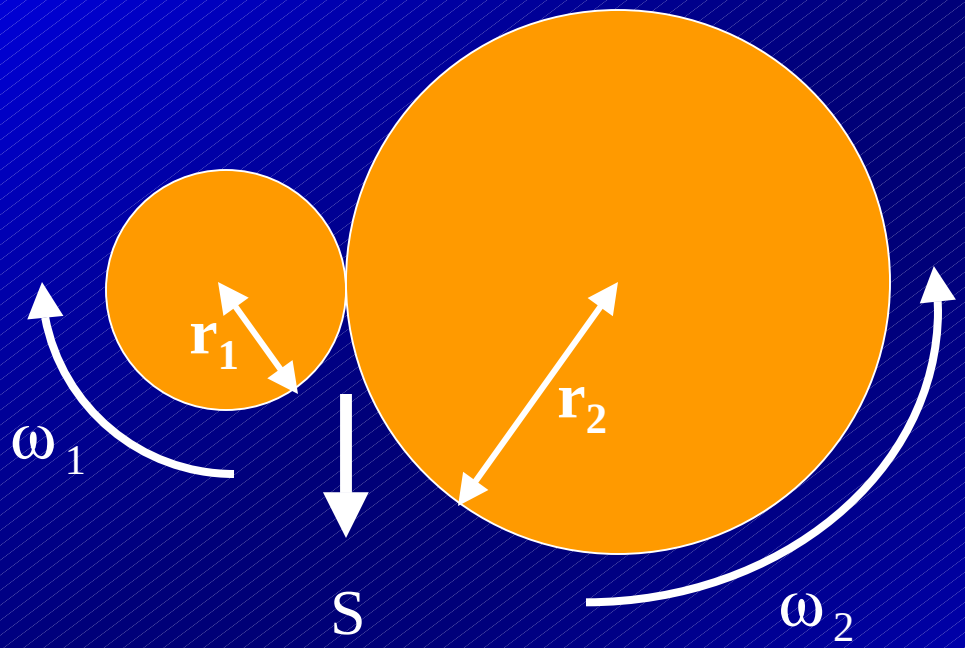


$$T_1 = F \times r_1$$
$$T_2 = F \times r_2$$

Since the force where the gears meet must be the same, then:

$$T_2 = \frac{r_2}{r_1} \times T_1$$

Gearing Basics - spur gears

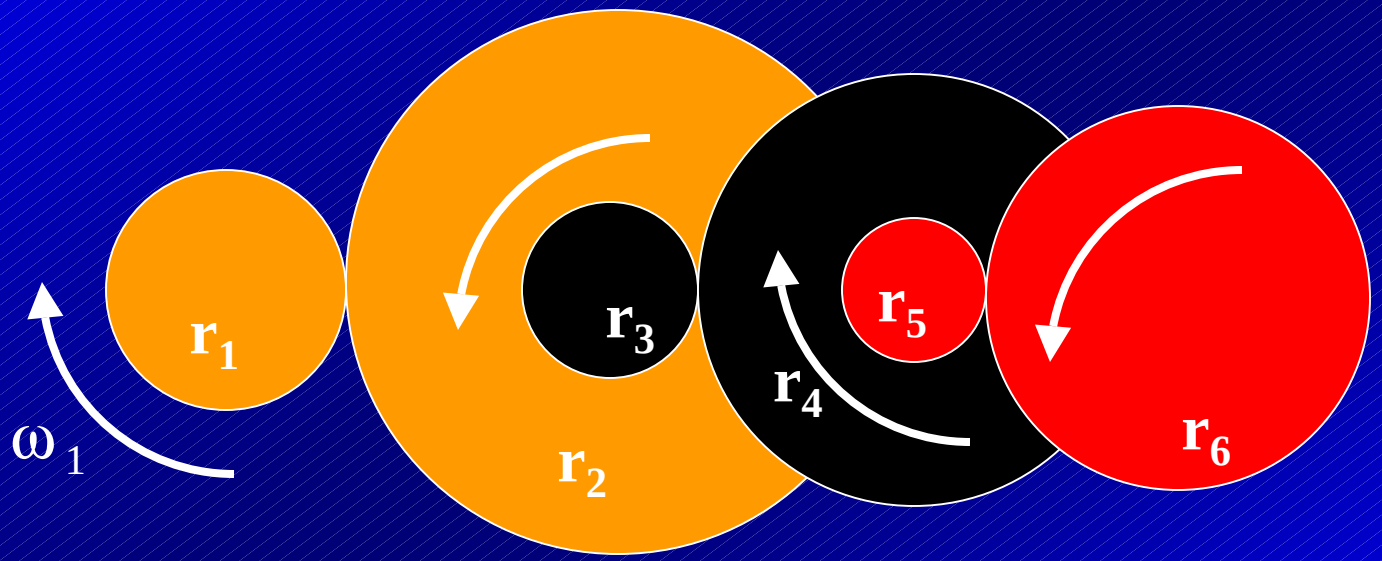


$$S_1 = \omega_1 \times \pi \times D_1$$
$$S_2 = \omega_2 \times \pi \times D_2$$

Since the surface speed where the gears meet must be the same, then:

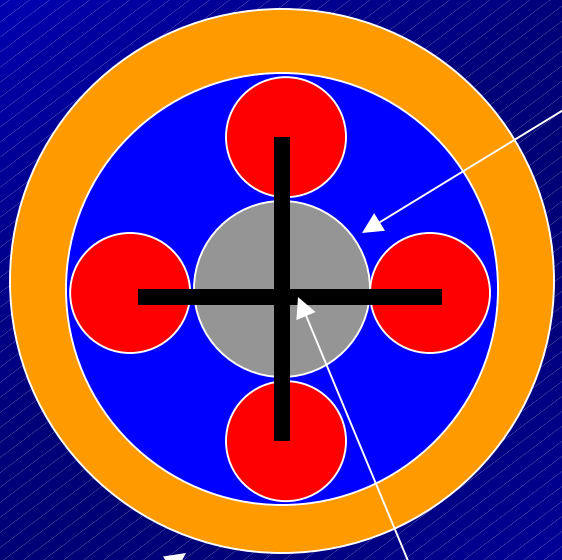
$$\omega_2 = \frac{r_1}{r_2} \times \omega_1$$

Gear trains



$$\omega_6 = \frac{r_1}{r_2} \times \frac{r_3}{r_4} \times \frac{r_5}{r_6} \times \omega_1$$

Planetary gears



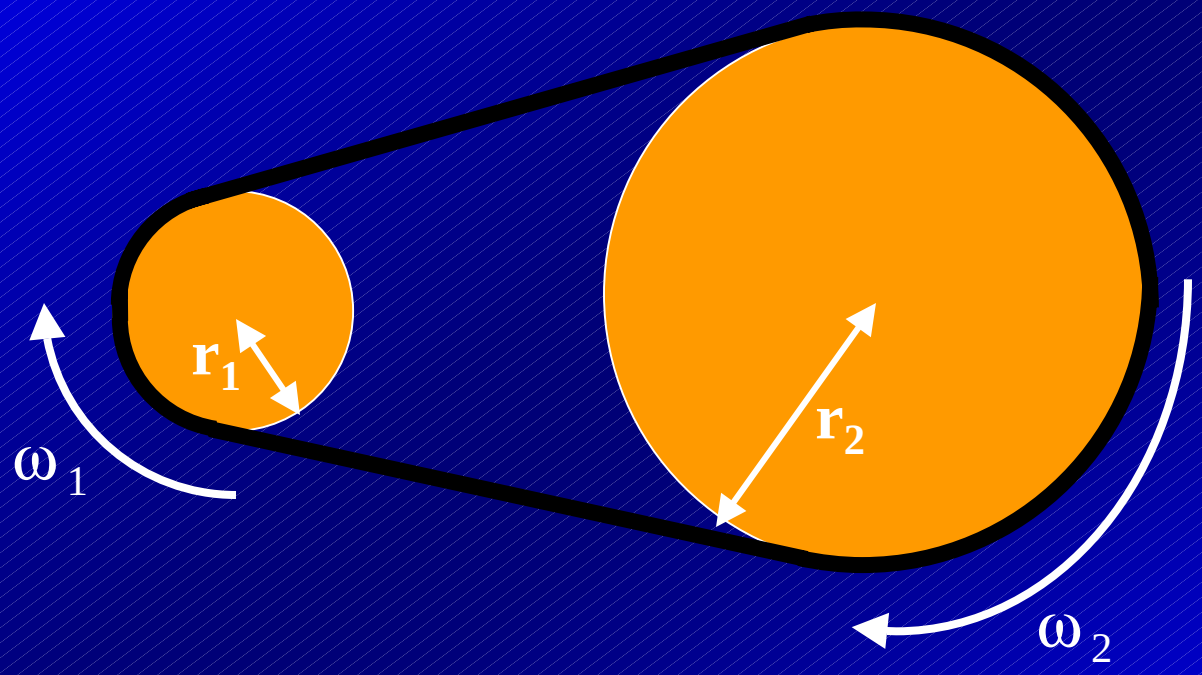
Driven gear, r_1

$$\omega_f = 1 + \frac{r_1}{r_2} \times \omega_1$$

Fixed gear, r_2

Follower

Chain Drive



$$\omega_2 = \frac{r_1}{r_2} \times \omega_1$$

$$T_2 = \frac{r_2}{r_1} \times T_1$$

Comparison of gearing Methods

	Spur	Planetary	Chain
Size	med	compact	large
Ease	easy	complex	easy
Weight	med.	light	heavy
Accuracy needed	med.	high	low
Direction	opp.	same	same
Reliability	med	med	high

Comparison of available motors

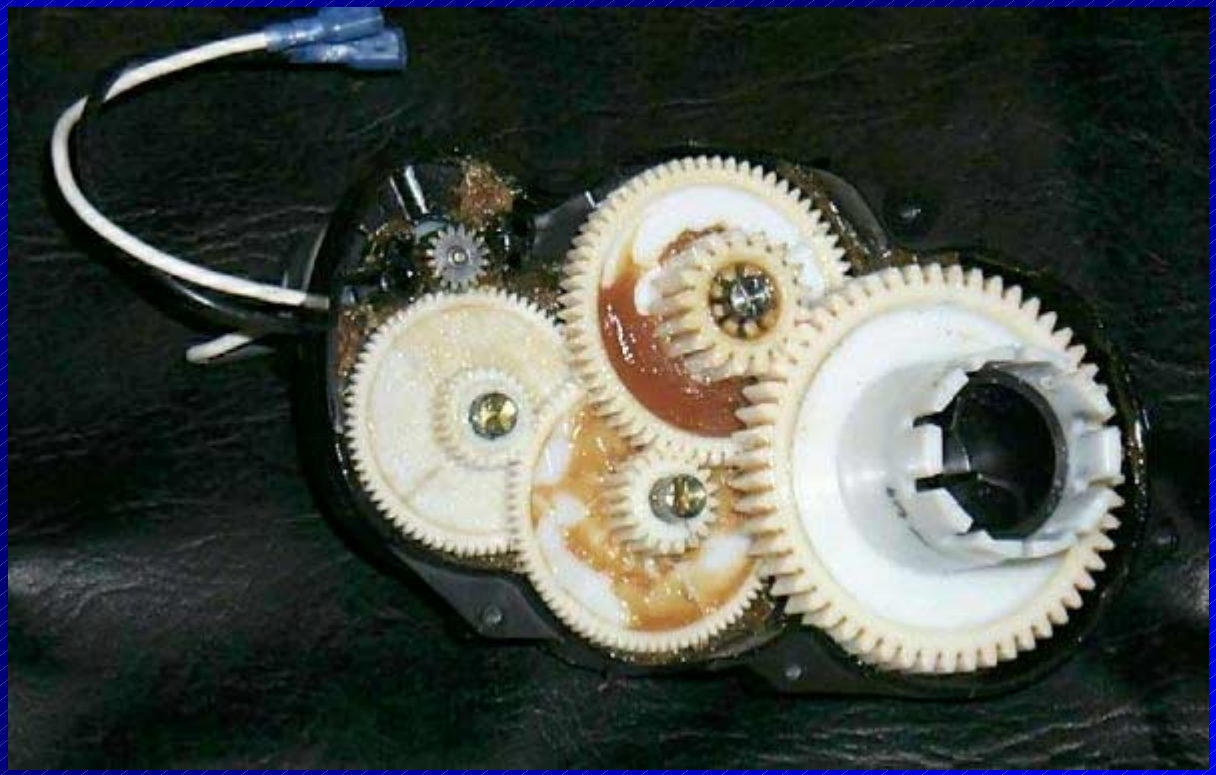
	Gear Box ratio	Gear Box efficiency	Stall Torque N-m	Stall Torque in-lbs	Stall Current amps	Free Speed rpm	Free Current amps	Peak Power watts	Weight lbs
Drill motor	-	-	0.65	5.8	127	18,000	5.32	376	
gearbox hi	11.6:1	65%	5.4	48	84	1550	5.8	193	
gearbox low	:1								1.01
Chiapua	-	-	2.2	20	107	5500	2.3	321	2.86
F-P motor	---	---	0.36	3.2	57	15000	---	140	
gearbox	147:1	65%	35	312.5	57	100	---	91	1.51
Van door motor	---	---	35	312.5	40	75	---	69	2.68
Globe motor	---	---	21	187.5	21	11500	0.82	63	
gearbox	117:1	77%	19	169.6	21	100	0.82	50	1.14
Window motor	---	---	12	107.1	20	70	---	22	1.83
Seat motor	---	---	2	17.9	20	600	---	31	

Other Considerations

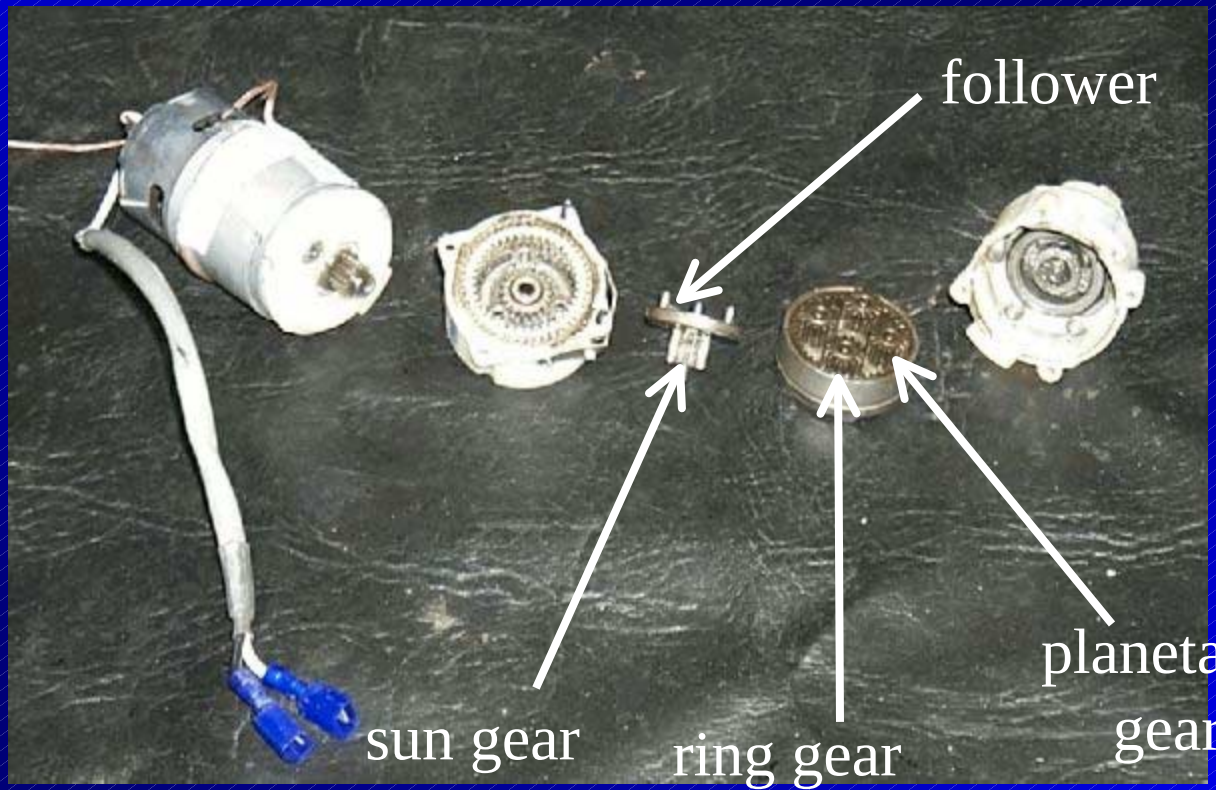
- Thermal Protection
  - The Drill, F-P, and Globe motors will work until they melt
  - The Window motor, Seat motor, Sliding door motor have thermal cut-offs to prevent overheating

Fisher-Price Motor

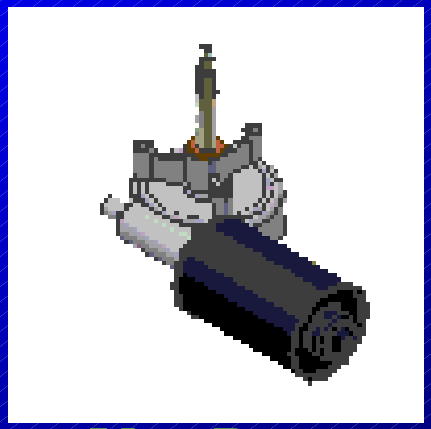
	1st	2nd	ratio
1	16	72	4.5
2	25	79	3.2
3	19	61	3.2
4	17	54	3.2
			145



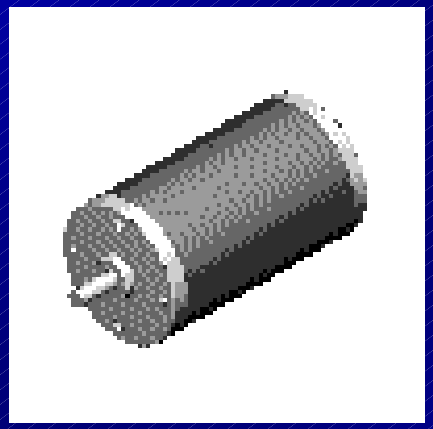
Bosch drill Motor



Other Motors

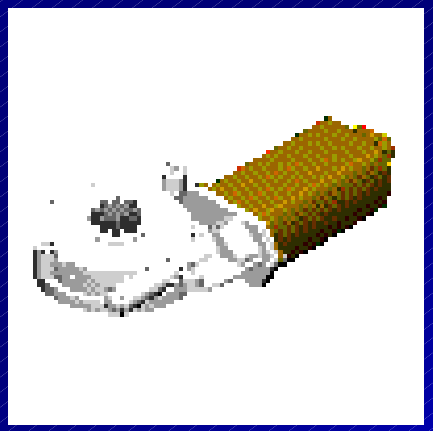


Van Door

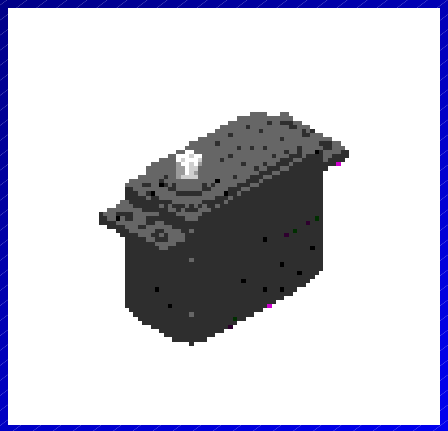


Chiapua

Globe



Window



Servo

GeroniMoe's vital stats drivetrain

2 Drill Motors
2 Chiapua Motors with custom gearbox
Total of 1.85 HP

Chain Drive with 1:1 ratio

5" diameter wheels

GeroniMoe's vital stats
Bin Lifter

1 Van Door Motor, with 75 rpm and 310 in-lbs

Multistage Chain Drive with 1.2x ratio
& 2" sprockets

…… 370 lbs of lifting capability

GeroniMoe's vital stats
Wings

2 Globe Motors, with 100 rpm and 170 in-lbs each

Direct Drive