Intro to Motors and Gears

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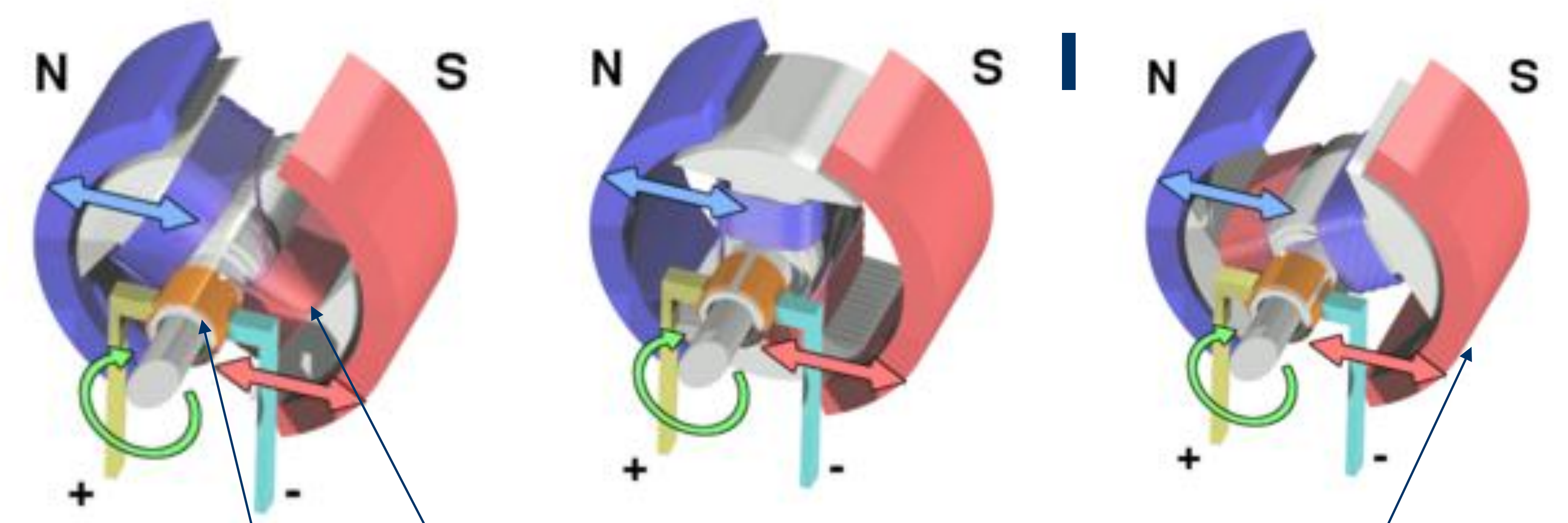
Agenda

- Types of Motors
- Motor Performance Specs
- Torque demystified
- Calculating Mechanical Advantage with Gears/Rollers
- Measuring Efficiency
- Demonstration: Computer Tools to Create Gears

DC “Brushed” Motor Rotation



the permanent magnets are stationary (stator)
and the armature rotates, changing field polarity
commutator transfers current to armature

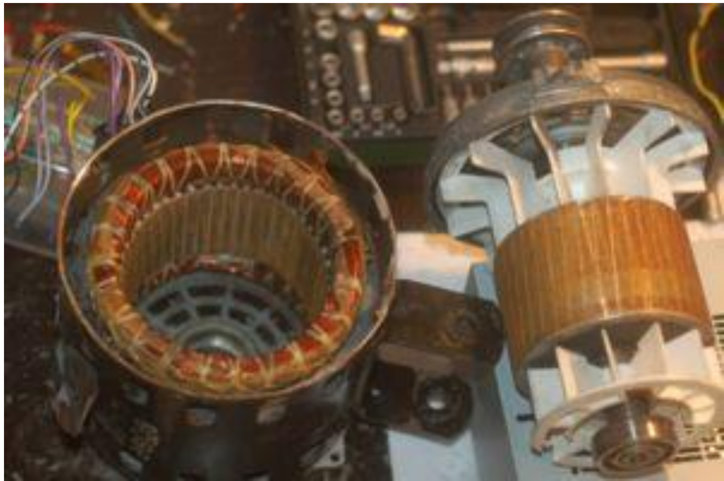
http://en.wikipedia.org/wiki/Brushed_DC_Electric_Motor

Brushless DC Motors

- More Powerful and Efficient
- More Costly--Electronics to control current
- the permanent magnets rotate and the armature remains static.
- Computer fan motor →
- Floppy Drive motor (above)

AC Motors

- Induction Motors (Tesla)
  - Kicked off 2nd Industrial Revolution, 1888
  - Need 3-Phase AC power
- Squirrel Cage Motors (common)
  - Washing Machines, Fans,
  - Dryers, Record Players



http://en.wikipedia.org/wiki/AC_motor

Our Motor Specs

- Radio Shack Gearless Motor
  - Voltage: 1.5 – 3 V
  - Current: .98 A at max efficiency
- Speed:
  - 11600 RPM at no load (RPM=Revs Per Minute)
  - 8300 RPM at max efficiency
- Shaft diameter ??
- Output ??
- Torque: ??

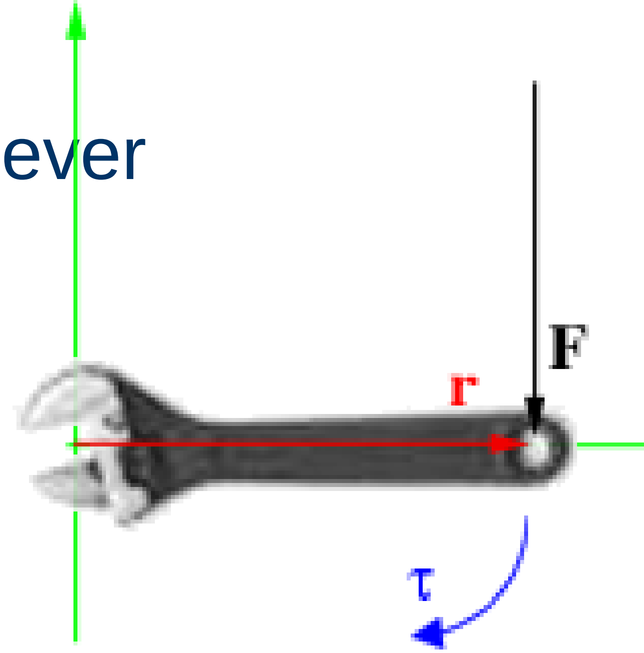
Our Motor Specs

- Radio Shack <u>Gear</u> Motor
  - Voltage: 1.5 – 3 V
  - Current: .18 - .25 at no load
.7 A at max efficiency
- Speed:
  - 8700 RPM at no load
  - 5800 RPM at max efficiency
- Shaft diameter .0787 mm (more like1.5 mm)
- Output .31 W
- Torque: 5.3 g/cm …is this accurate?

What is Torque?

- Also called Moment
- A rotational force applied to a lever
- Using 3D Vector Notation
  - $\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$
- In 2 Dimensions

$$T = (\text{distance to center}) \cdot \text{force}$$



- A force of 3 Newtons applied 2 meters out = force of 6 Newtons applied at 1 meter = **6 N-m**

http://en.wikipedia.org/wiki/Torque

Angular vs Linear Motion Analogies

- Linear Motion:
  - force, mass, acceleration
- Angular Motion:
  - torque, moment of inertia, angular acceleration

Some Other Units of Torque

- Torque = Force x Distance
- SI Units: Newton-Meters (1N = 1 kg-m/s^2)
- English Units:
  - Foot-Pounds
  - Oz-Inches (for small motors)
- Q: what is our gearmotor unit?
  - A: 5.3 g/cm ????
  - see: http://www.shinano.com/xampp/skvconv.swf

Converting Units of Torque

- The method of unit analysis:
  - 5.3 g-cm = 5.3 x $\frac{1\ kg}{1000g}$ x $\frac{2.2\ lb}{1\ kg}$ x $\frac{16\ oz}{1\ lb}$ x $\frac{1\ in}{2.54\ cm}$

    = .06929 oz-in

- What about N-m ? A Newton = 1 kg – m/s^2
  - The force of 1 kg accelerated 1 m/s^2
  - But on Earth, 1 kg is subject to g= 9.8 m/s^2

Converting N-m to ft-lbs

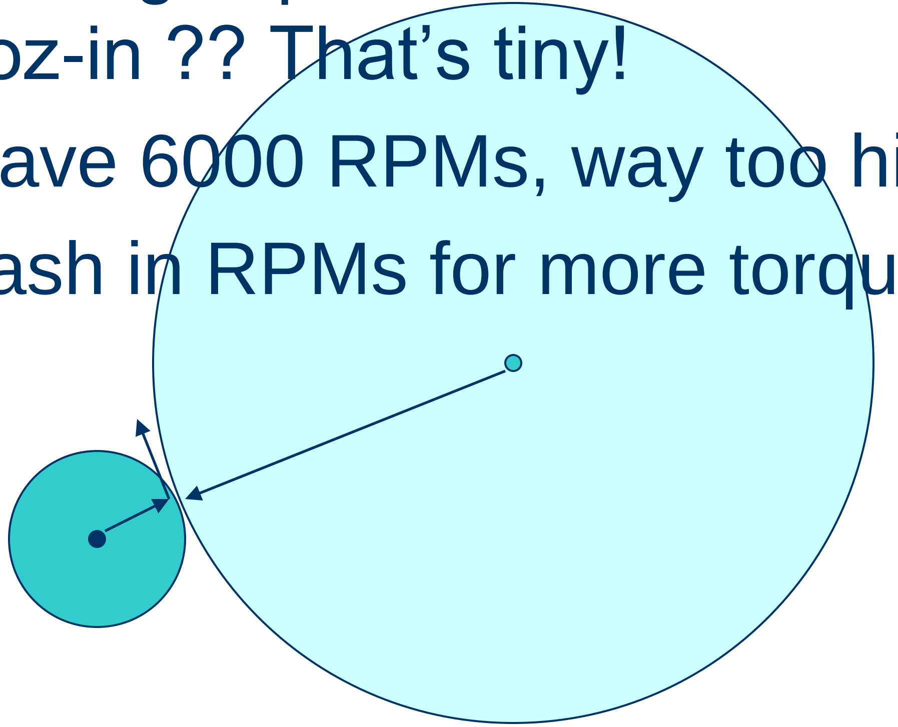
- To go from N-m to ft-lbs, first remove the contribution of g, gravitational acceleration:

50	N-m	=	5.098581	kg *	9.80665	m/s2 *	1	m
		=	11.21688	lb *			3.28	ft
		=	36.79136	ft-lb				

- In other words, 50 N-m is like putting a 5.1 kg mass on the end of a 1m wrench and letting gravity (g) pull it down
  - Or a 36 lb weight on a 1 ft wrench
  - Or a 1 lb weight on a 36 ft wrench

Gearing Up Torque

- The Torque of a high speed DC motor is very small…0.069 oz-in ?? That's tiny!
- However we have 6000 RPMs, way too high
- Gears let us cash in RPMs for more torque

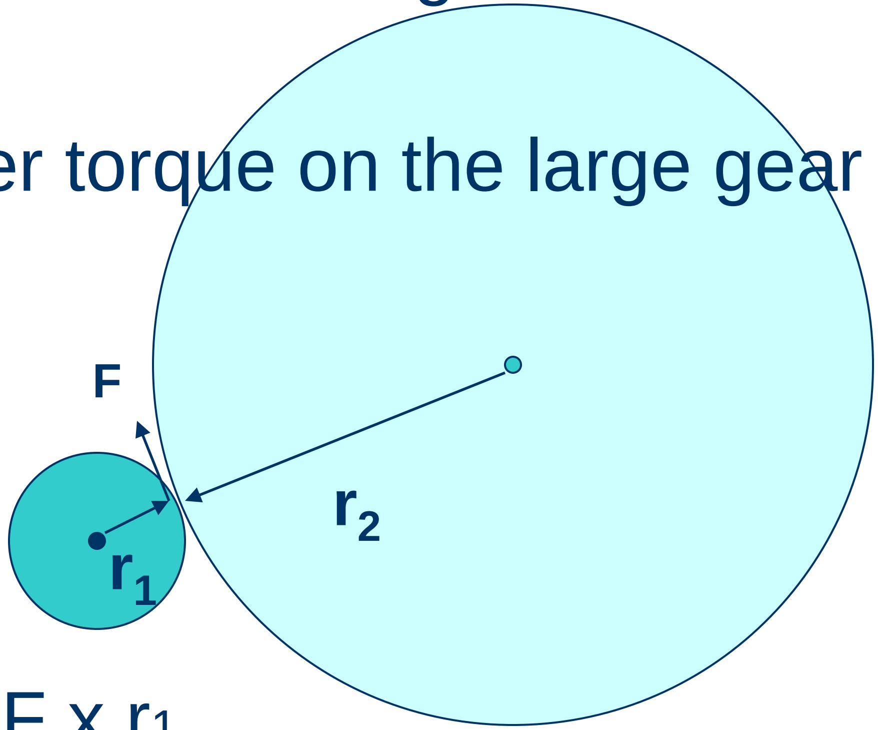


How it works

- The force applied at the edge of the small gear
  - $F = T_1/r_1$
- Creates greater torque on the large gear

$T_2 = F \times r_2$

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



$T_1 = F \times r_1$

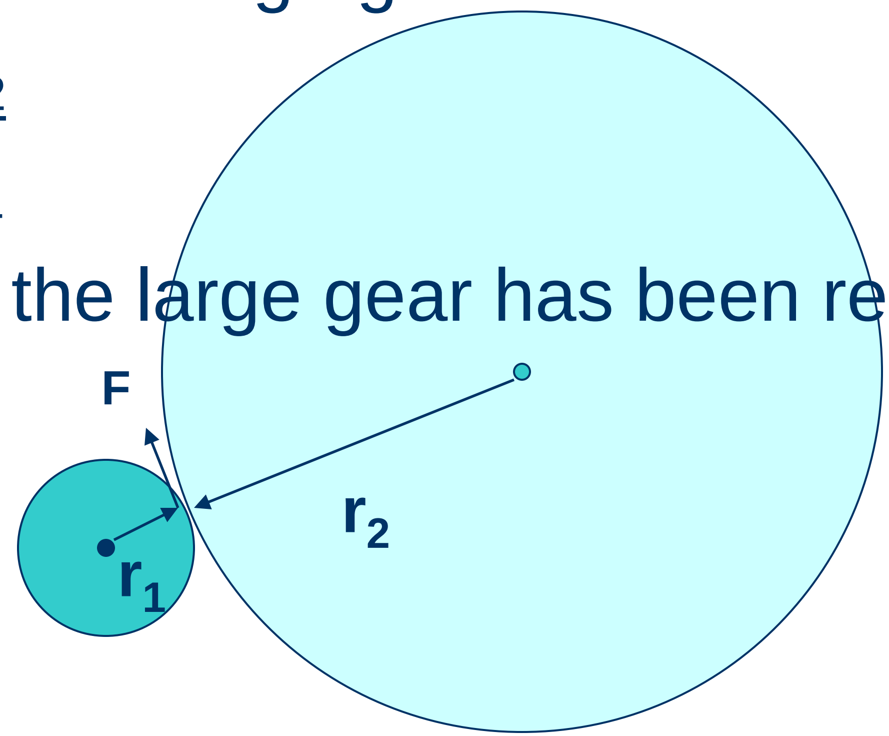
Effect on RPM (angular velocity)

- The Torque on the large gear has been amplifed

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

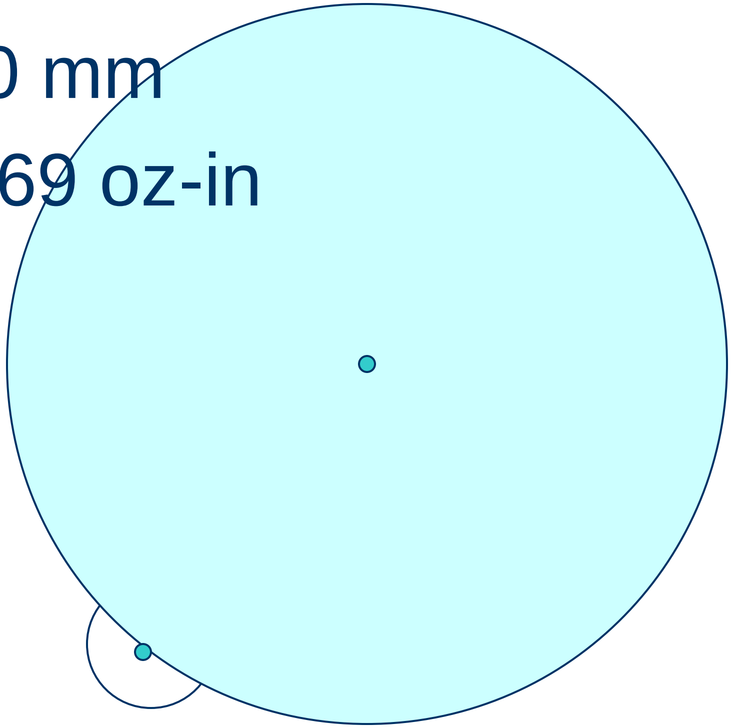
- The speed on the large gear has been reduced

$$w_2 = w_1 \times \frac{r_1}{r_2}$$



The Example of Spindle to CD

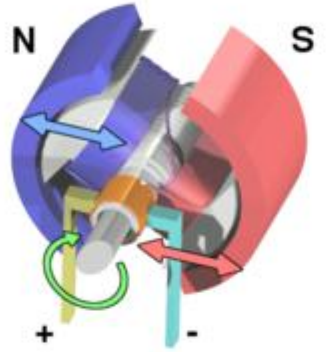
- Motor Shaft Diam=1.5mm
- CD Diameter = 120 mm
- Motor Torque= 0.069 oz-in
- CD axle Torque
  - =.069*(120/1.5)
  - =5.5 oz-in
- CD RPM
  - =6000*(1.5/120)
  - =75 RPM



Power Efficiency in Motors and Gears

- These are ideal calculations
  - In reality, there are losses due to friction, slippage
  - Also, the motor itself is not 100% efficient
  - As Engineers, we will be very interested to learn what the efficiency of our machine is
    - And how to optimize it

Efficiency of Motors

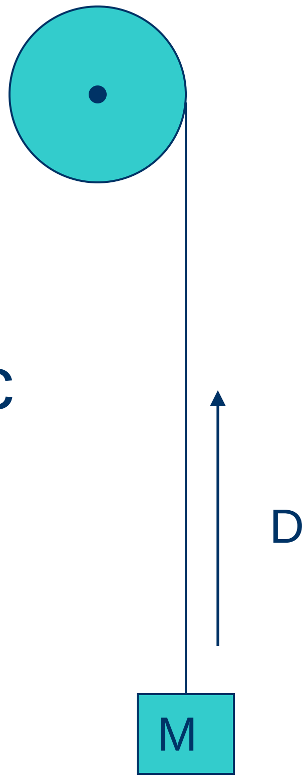


- Motors convert Electrical Power into Mechanical Power
- Input Power is the product of Volts x Amps
- What about output power?
  - Power = Energy/Time
  - Energy = Force*Distance (= Torque*Angle)
  - Therefore Power = Force * Distance/Time or F*v

To Measure Motor Output Power

- We can set up a spool to wind a string
  - If we can raise a Mass M (kg) by D (m) in T (sec)
  - We are applying a force M*g over D m/T sec
  - Power = M*g*D/T
- Suppose M= 0.5 kg, D=0.5m and T=2 sec
  - Power = .5* 9.8 * .5 / 2   kg-m^2/s^2

    = 1.225 Watts



Efficiency

- Suppose in the previous test we measured the motor drawing .5A of current at 6 V.
  - Pin = .5 * 6 = 3 W
  - Pout = 1.225 W
- Efficiency is just Pout/Pin converted to %
  - Efficiency = 1.225/3 = .408 = 40.8%

What about measuring Torque?

- We can take the data from the last example:
  - F = M g = .5*9.8 = 4.9 kg – m/s2 = 4.9 N
  - Suppose the Radius of the spool is 2 cm
  - Torque = 4.9 * .02 = .098 N-m

Big Picture

- This is essentially how the whole power grid works. A generator (opposite of motor) creates electricity, wires distribute it, and then it runs our appliances (motors, TVs, etc) with a certain efficiency at each step. If we can improve the efficiency, we can reduce fuel expenses, save $$ and resources, etc.
- Engineers are all about improving efficiency (through ingenuity…for example LED lighting)