MS4SSA Robotics Modules:
Mechanisms

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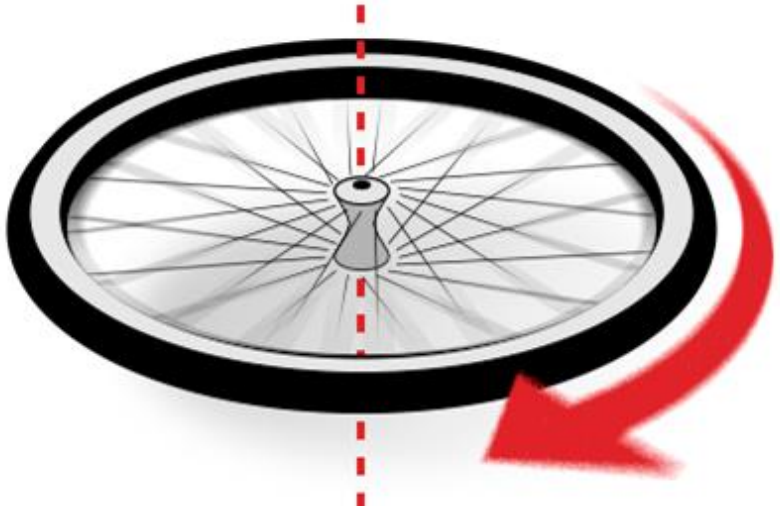
Lesson Outline:

- Overview of Electric DC Motors
- How DC Motors Work
  - Motor Power Curve
- Overview of Power Transmission
  - Speed & Torque ratios
- Hands-on Exercise:
  - Horizontal Test
  - Inclined Test

DC Motors

What Do Motors Do?

They generate **ROTATIONAL MOTION!**



Where do we have Motors?

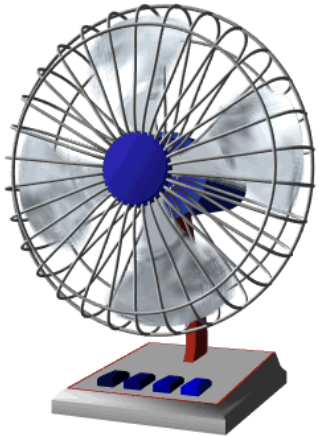
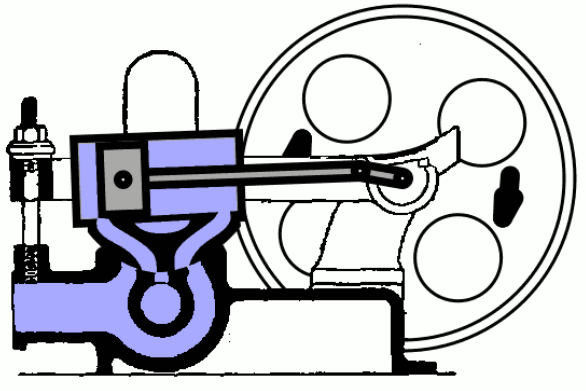


Table Fan

Kitchen Blender



Pump

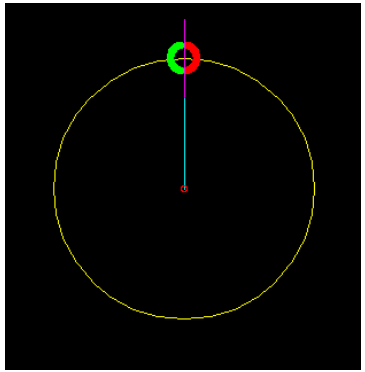
Where else do we have motors?

Explaining Torque & Angular Speed

- How fast are these objects rotating?
  - Discuss

A

B



Explaining Torque & Angular Speed

- What's the easiest means of rotating your laptop lid or door knob?
  - Discuss

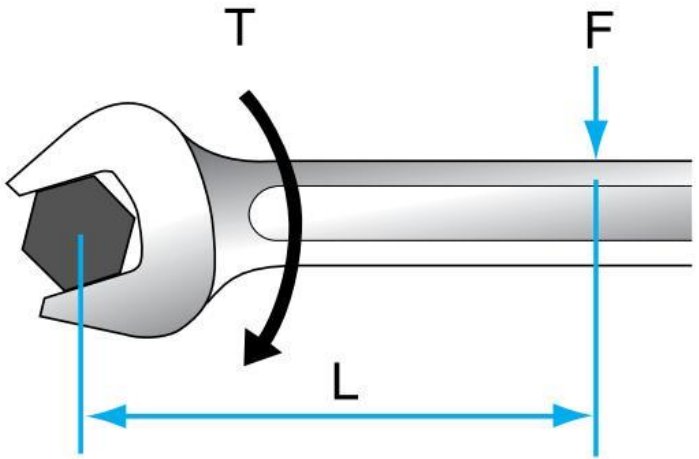
Explaining Torque & Angular Speed

Torque is the action that causes an object to rotate.

Rotation always happens about a center.

To achieve same torque,

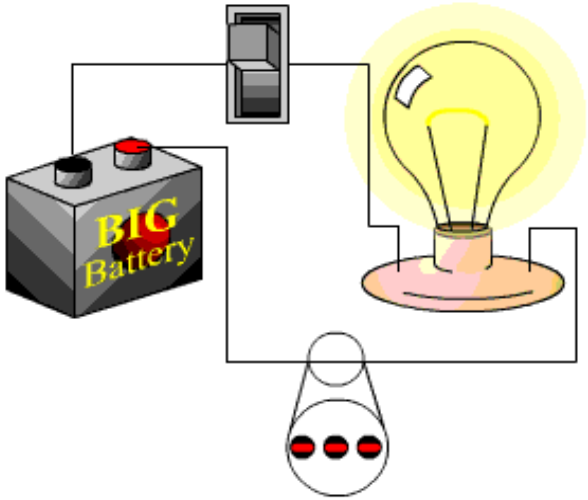
- **More distance = (more/less) force**
- **Less distance = (more/less) force**



Torque T = F (Force) × L (Length)

So, where does this **force** that turns the motor shaft come from and where is the **distance**?

Electricity: Current and Voltage



How does electricity work?

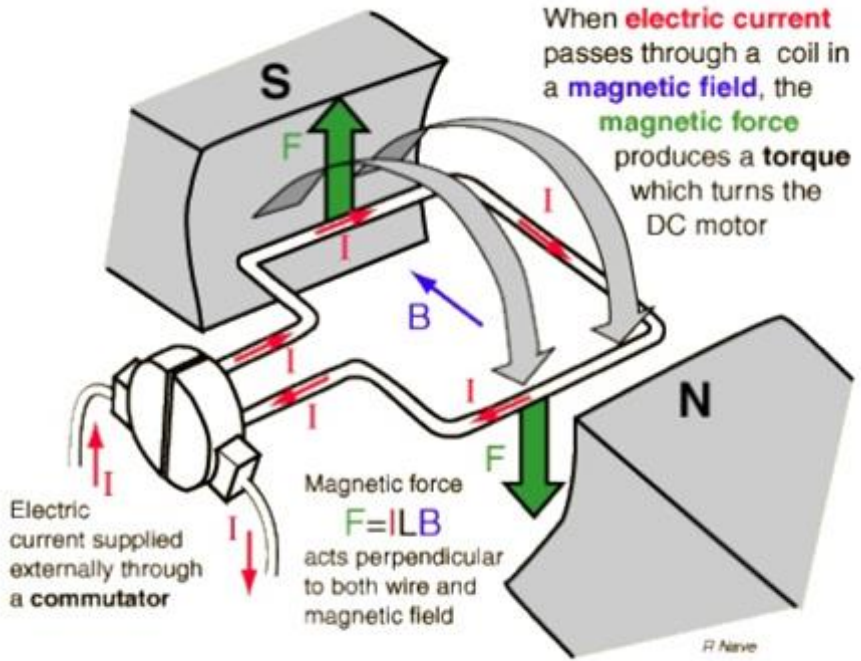
- Discuss

Voltage = Current x Resistance

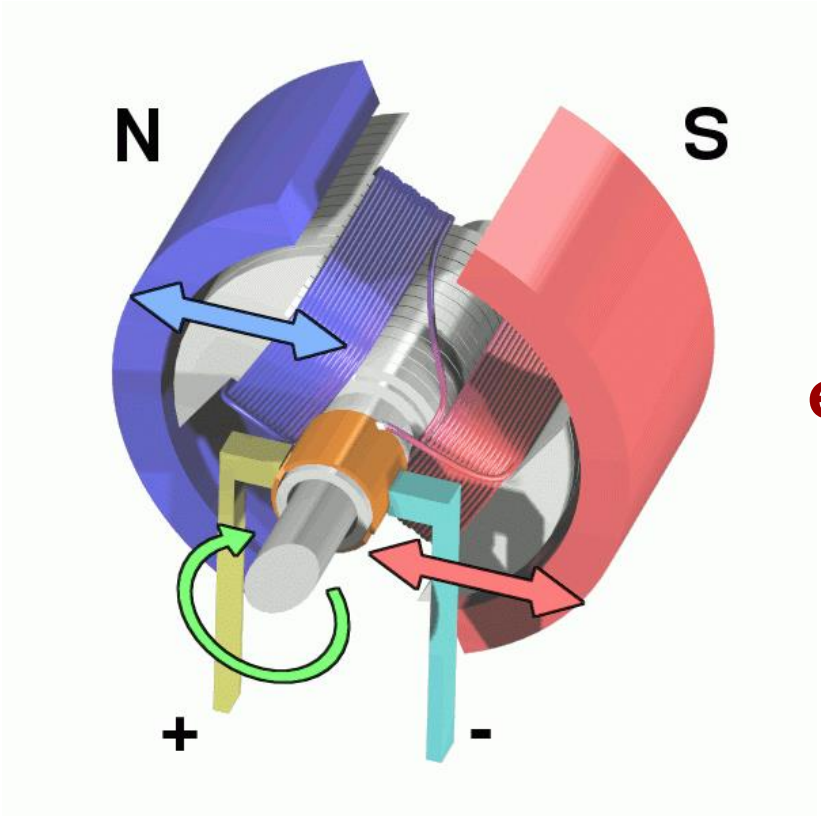
V = I x R

How do DC Motors Work?

- DC stands for **Direct Current**
- **Voltage, V,** at the terminals of the motor generate flow of **current, I.** (V = I x R)
- **Current, I,** through the coils in the motor generate a **magnetic field, B,** which induces a **magnetic force, F.** (F = IL x B)
- **Force, F,** on the rotor of the motor generates a **torque, T,** at the motor shaft. (T = r x F)



How do DC Motors Work?



Therefore,
DC motors convert
electric energy (current) to
mechanical energy
(rotation of a body)

Important Concepts about Power

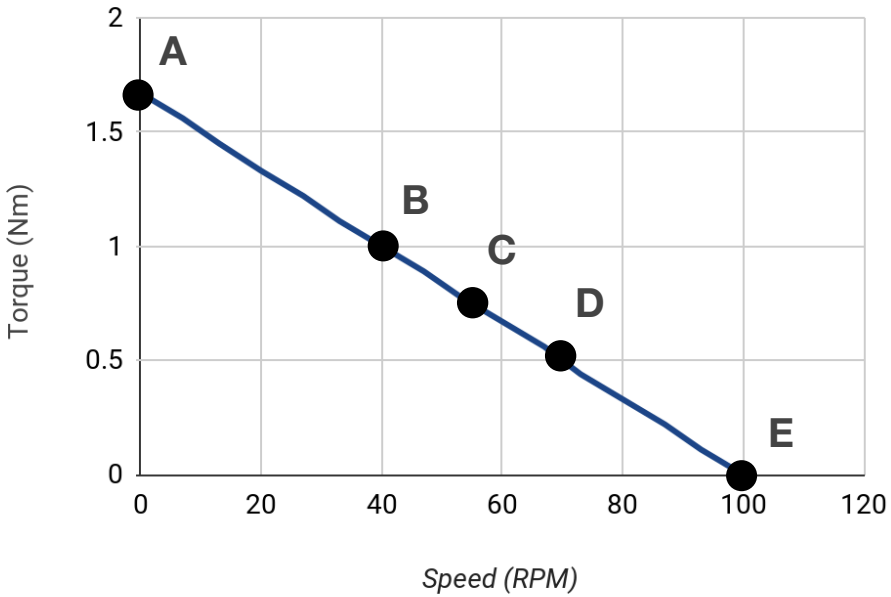
- When you pedal a bicycle, you apply forces to a rotating body and do work on it.
- **Power** is the rate at which you are doing that work.
- When a **torque T** acts on a body that rotates with **angular speed S**, its **power** (rate of doing work) is the product of the torque and angular speed.

Power = Torque x Angular Speed

P = T x S

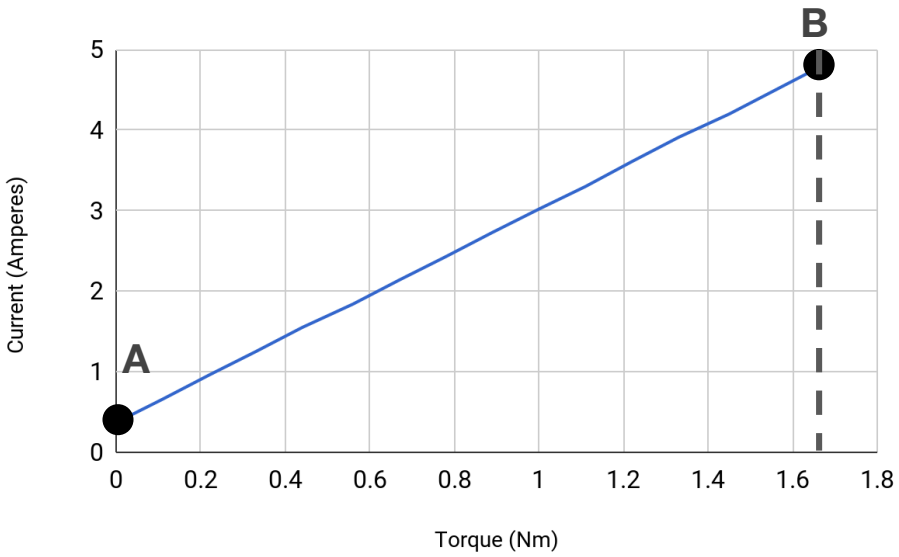
Motor Power Curve

- Torque-Speed Curve



1. What is the **speed** and **torque** at A?
2. What is the **speed** and **torque** at D?
3. What is the **power** at B?
4. What can you say about the **torque-speed** relationship?

Motor Power Curve



1. What is the **current** and **torque** at A?
2. What is the **current** and **torque** at B?
3. What can you say about the **torque-current** relationship?

Motor Power Curve

What is the power at

A =

B =

C =

D =

E =

Can you draw a graph of power against torque?

Motor Power Curve

What is the **power** at

A = 0.00 Watts

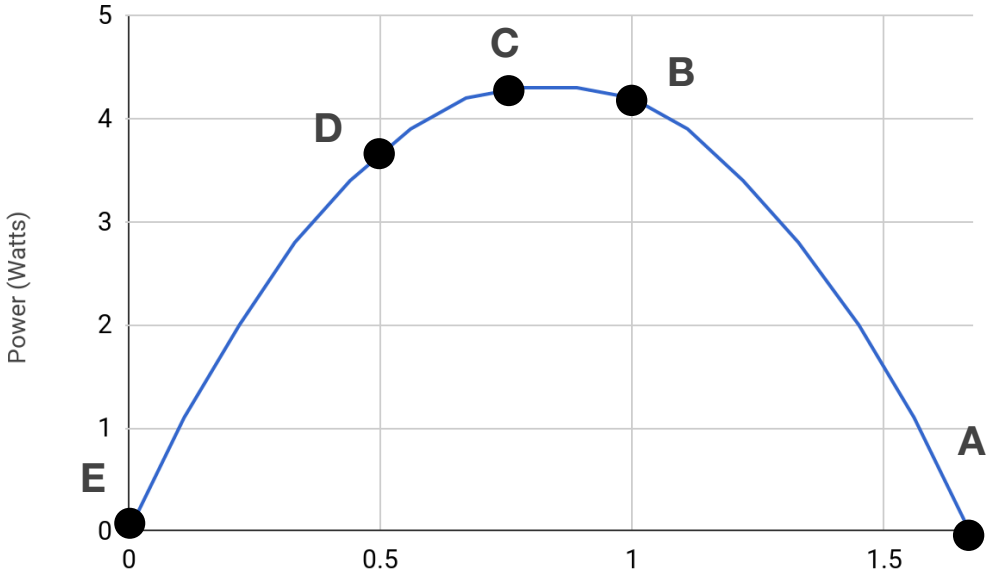
B = 4.19 Watts

C = 4.30 Watts

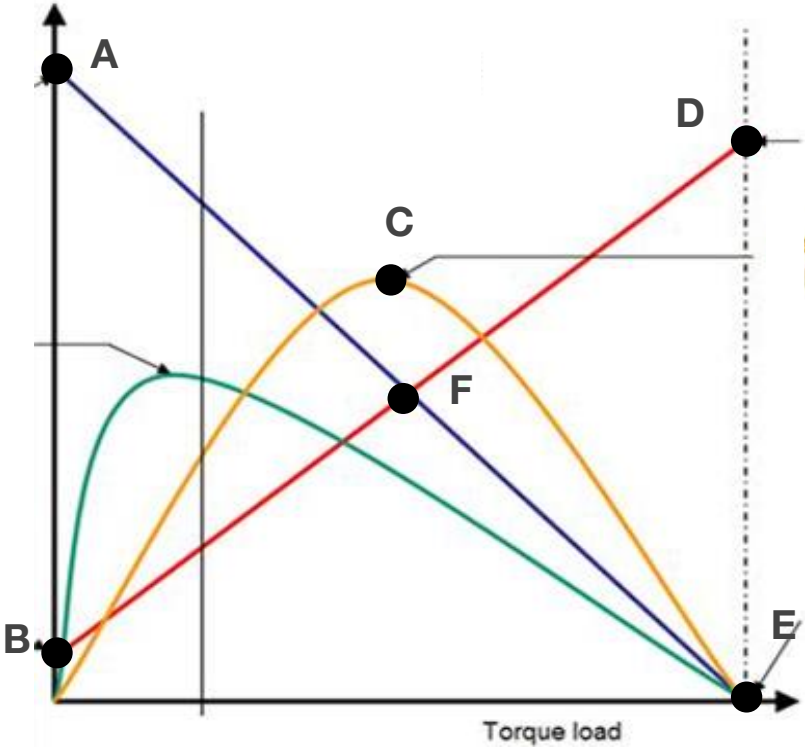
D = 3.66 Watts

E = 0.00 Watts

Can you draw a graph of **power** against **torque**?



Motor Power Curve



Let's play a matching game:

A
B
C
D
E
F

Maximum current in the motor
Maximum torque generated
Maximum power in the motor
Maximum speed of the motor
Minimum current in the motor

DC Motors in the Robotics Kit?

VEX 2-wire 393 Motor

Motor Specification Sheet

Voltage (V)	7.2 Volts
Stall Torque (T)	1.67 N-m
Free Speed (S)	100 RPM
Stall Current (I)	4.8 Amps
Free Current (I)	0.37 Amps

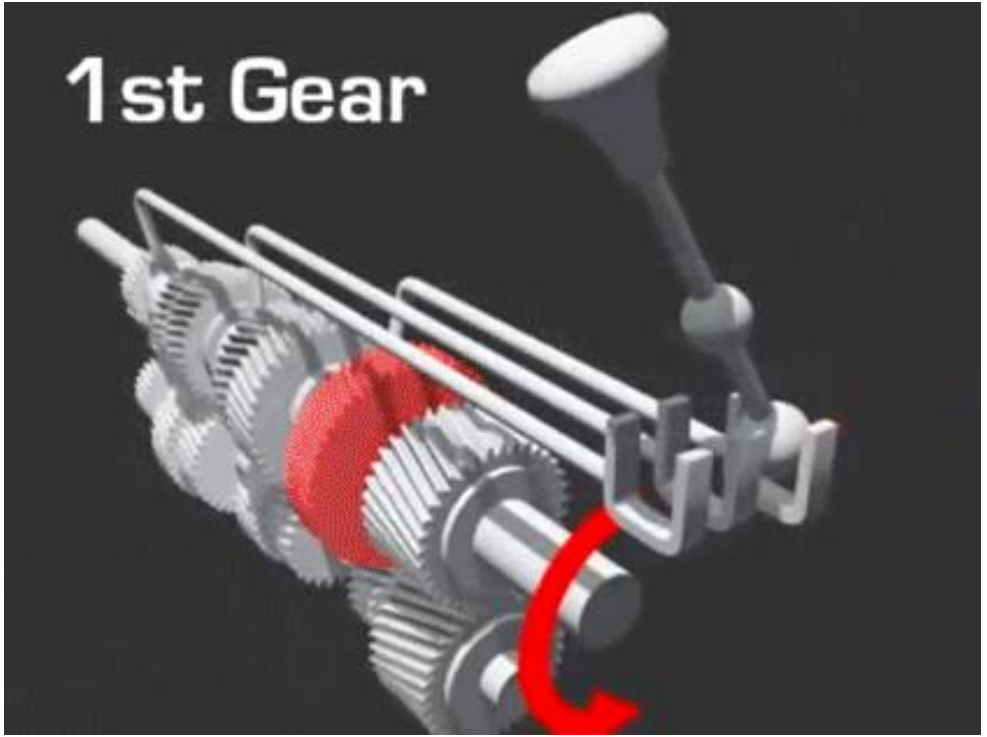
What do these mean?

Power Transmission

Power Transmission

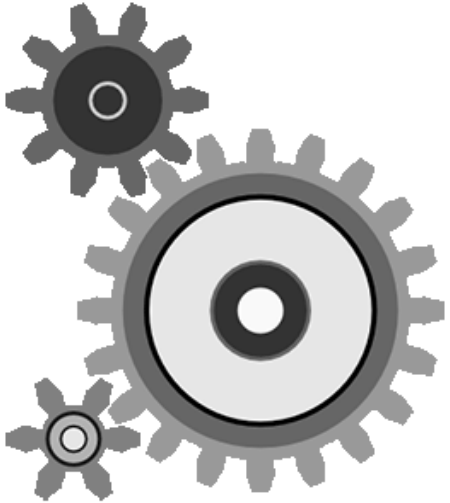
How do we change **speed** using the gear in a car?

It is done through the **power transmission** system!



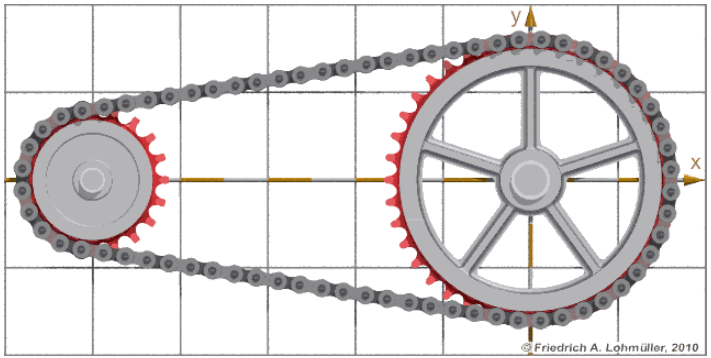
Power Transmission

They manipulate **torque** and **speed** of mechanical systems



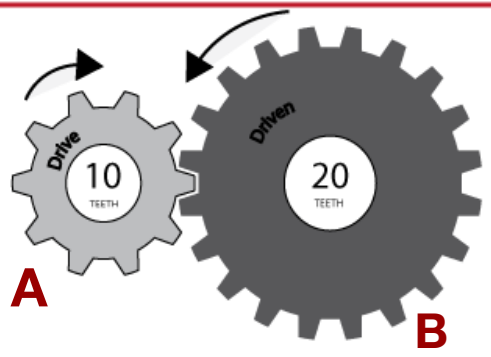
Common types:

- Spur Gears
- Chains & Sprockets
- etc.

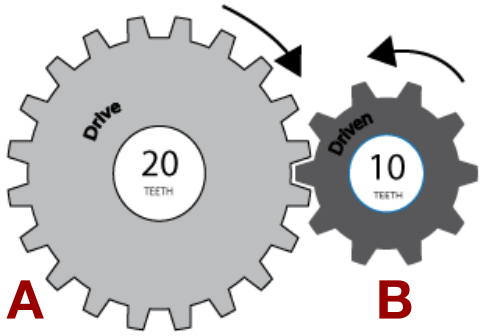


Gear Ratios

Gear reduction occurs when the drive gear is smaller or has fewer teeth than the driven gear.



Overdrive occurs when the drive gear is larger or has more teeth than the driven gear.



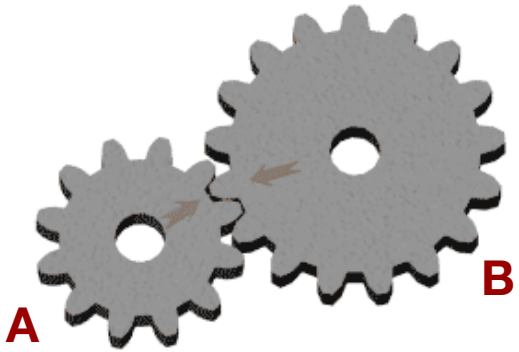
- No. of Driver gear teeth, N_A
- No. of Driven gear teeth, N_B
- Speed Ratio, $e = N_A/N_B$

- Gear Reduction
  - $e < 1$
  - Speed of B < Speed of A
  - Torque of B > Torque of A

- Overdrive
  - $e > 1$
  - Speed of B > Speed of A
  - Torque of B < Torque of A

Practice Questions:

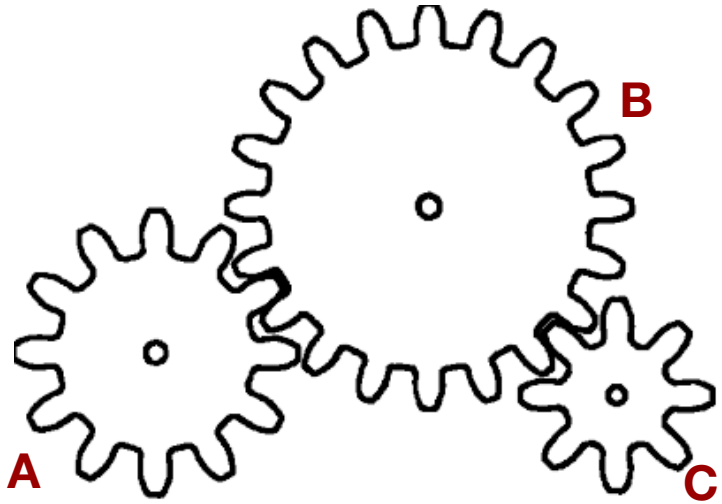
Practice 1:



N_A = 12 teeth, N_B = 24 teeth,
Speed of A = 100 RPM

Find e, speed of B & torque of B

Practice 2:



N_A = 12 teeth, N_B = 24 teeth, N_C = 8 teeth, Speed of A = 100 RPM

Find e, speed of B & C and torque of B & C

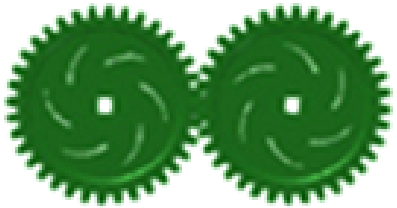
Hands-on Exercise

Hands-on Exercise

- **Horizontal Test**

We will compare the speed of the basebot using two speed ratios:

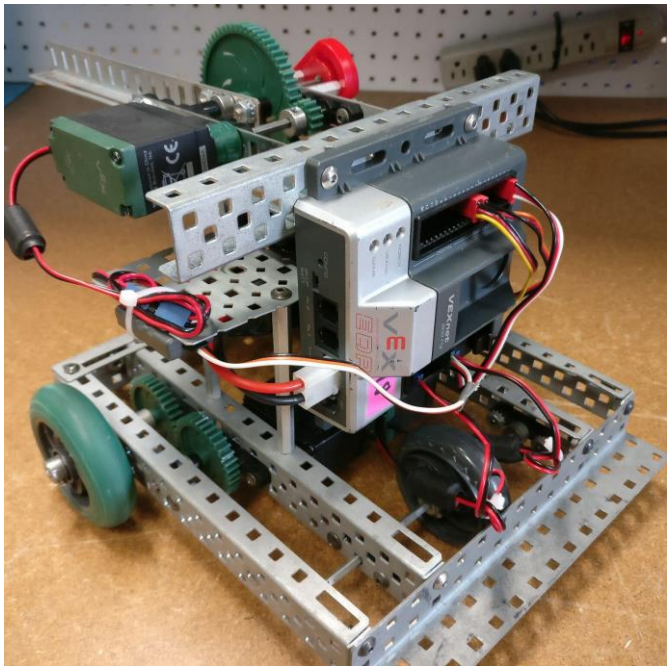
- **36:36, e = 1**
- **60:12, e = 0.2**



36:36 = 1

60:12

12/60 = .2



Hands-on Exercise

- **Horizontal Test**

    1. Measure the speed of the basebot using both ratios:

    1. Conduct the basebot race!

	36:36 (s)	60:12 (s)
Trial 1		
Trial 1		
Trial 1		
Average		

Intuition:

- Which gear setup is faster?
- Why is this so?
- How is this applied in a competition?

Hands-on Exercise

- **Inclined Test**

We will compare the **wheel torque of the basebot** using two speed ratios:

- 36:36, e = 1
- 60:12, e = 0.2

This test would be implemented while trying to climb an inclined plane.

The loading on the basebot has been adjusted to demonstrate the impact of speed ratio on available wheel torque.

Hands-on Exercise

Intuition:

- Which gear setup completed the task?
- Why is this so?
- Why does the 60:12 robot stall?
- How is this applied in a competition?

What have you learned?

Acknowledgement

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