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CS450HO
Ms. Clark

CS450HO Homework 11.10.2021

Question 1: Brushed and Brushless Motors

- **Find an internet resource that explains the difference between brushed and brushless motors. Describe the differences in your own words. Include the link to your chosen webpage.**

https://www.automate.org/blogs/brushed-dc-motors-vs-brushless-dc-motors
https://cordlessdrillzone.com/drill-wars/brushless-vs-brushed-motor/

Brushed DC motors use a two-pole electromagnet made of a configuration of wire coils, called the armature. The electromagnet's poles pull and push against permanent magnets that line the outside of the motor. A device called the commutator facilitates the flow of current through the armature and reverses the polarity of the electromagnet when needed. On the other hand, a brushless motor does not need a physical switch to transmit the current. A brushless DC motor uses a sensor to track the position of its external rotor (which is a permanent magnet). The sensor then activates the coils in a structured way, unlike a brushed motor. Essentially, a brushed motor has brushes contacting the rotor, while a brushless one does not.

Question 2: Motor Specs

- **List and define with units the most useful motor specs.**

- Speed, measured in revolutions per minute
- Torque, measured in either inch-pounds or newton-meters
- Peak power, measured in watts

Question 3: Motors for Mechanisms

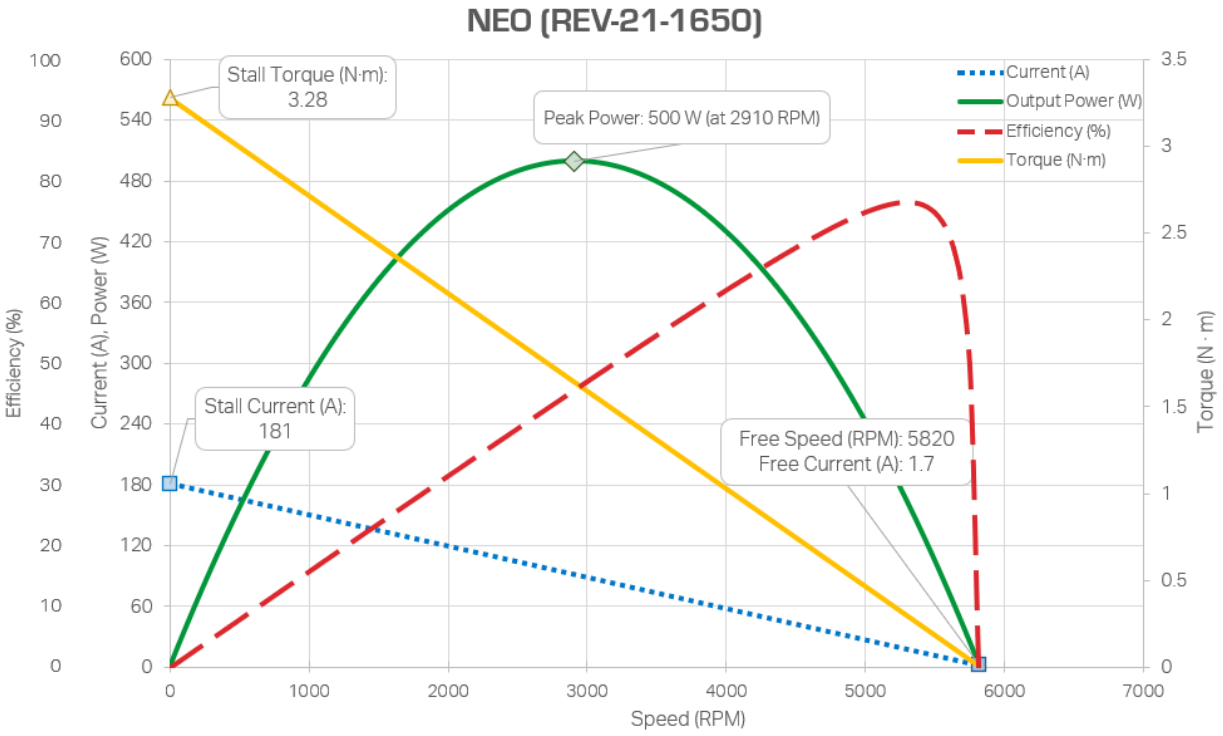
- **Which motors are best for intakes? Drivetrains? What are the similar properties of these motors based on use case?**

REV NEO motors are the best motors for intakes because they have a high speed. They are designed as a drop-in, brushless replacement for CIM motors. VEX Falcon 500s are the best motors for drivetrains because they have the highest peak power and torque of all the most common motors for FRC.

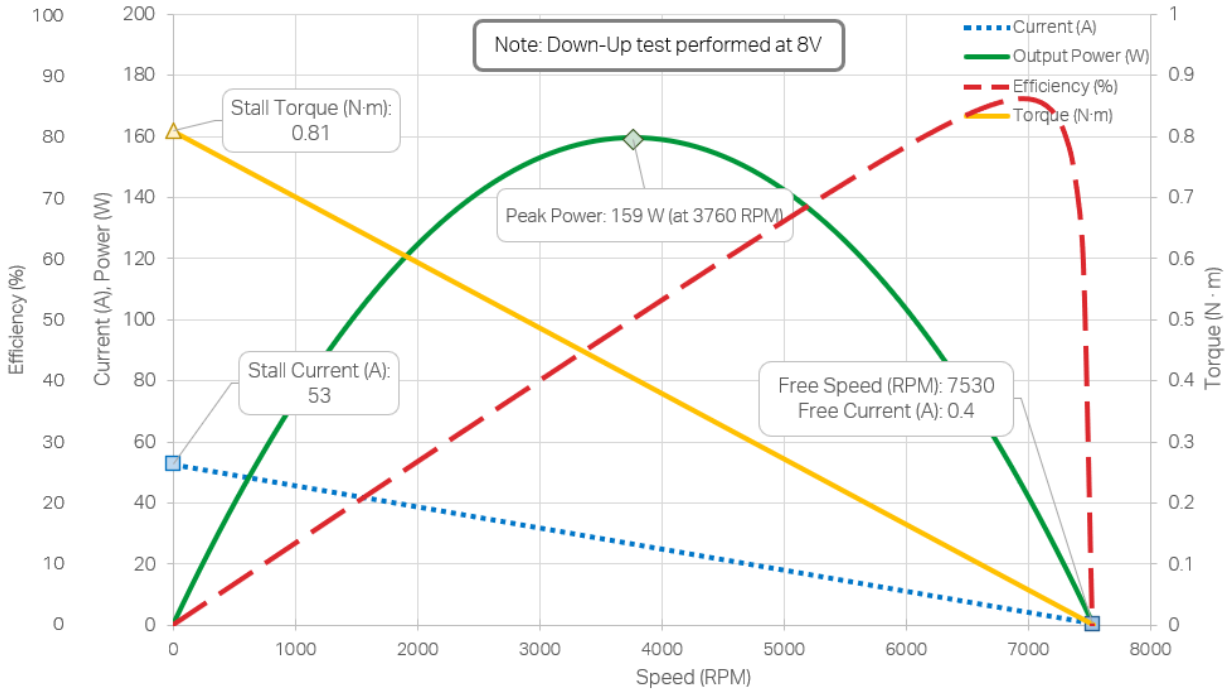
Question 4: Motor Curves

- **Watch the 973 motor curve video. Explain in your own words how a motor curve works. Paste images of the motor curves for a NEO, NEO550, RS775 Pro, CIM and a Falcon 500.**
    - **FRC 973 Motor Curve Video**

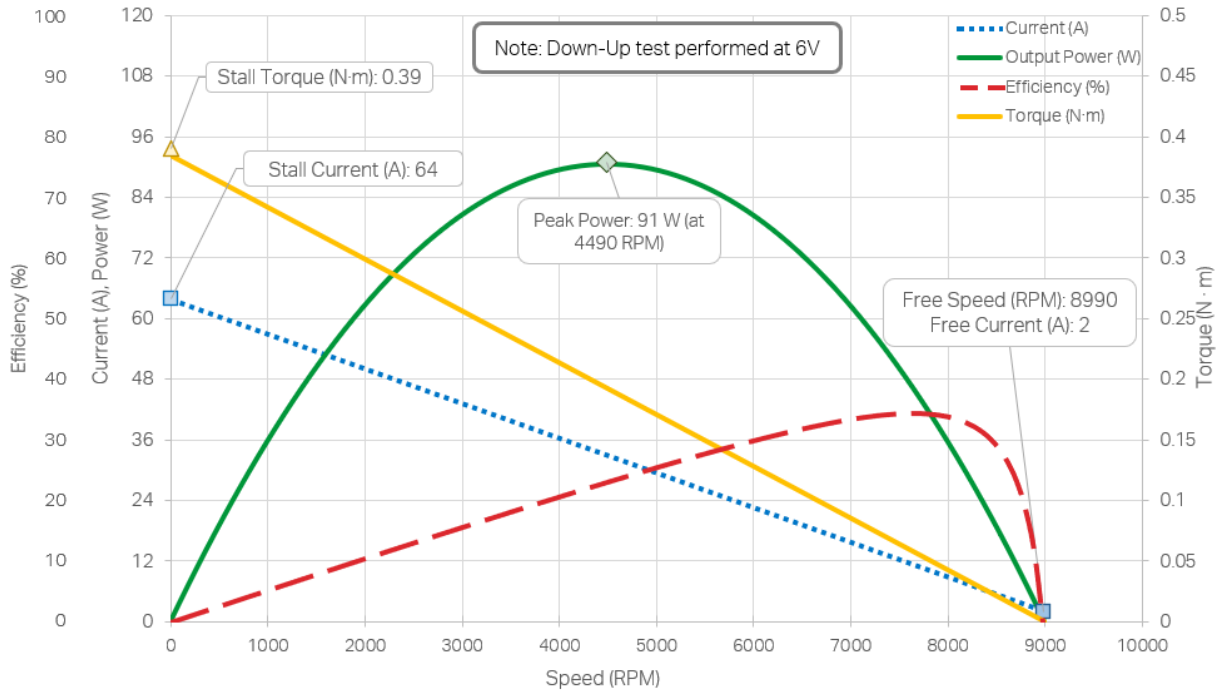
Motor curves are charts that that determine the torque output at a specific speed. They can tell us the speed, current, efficiency, and power of a motor in a given situation.

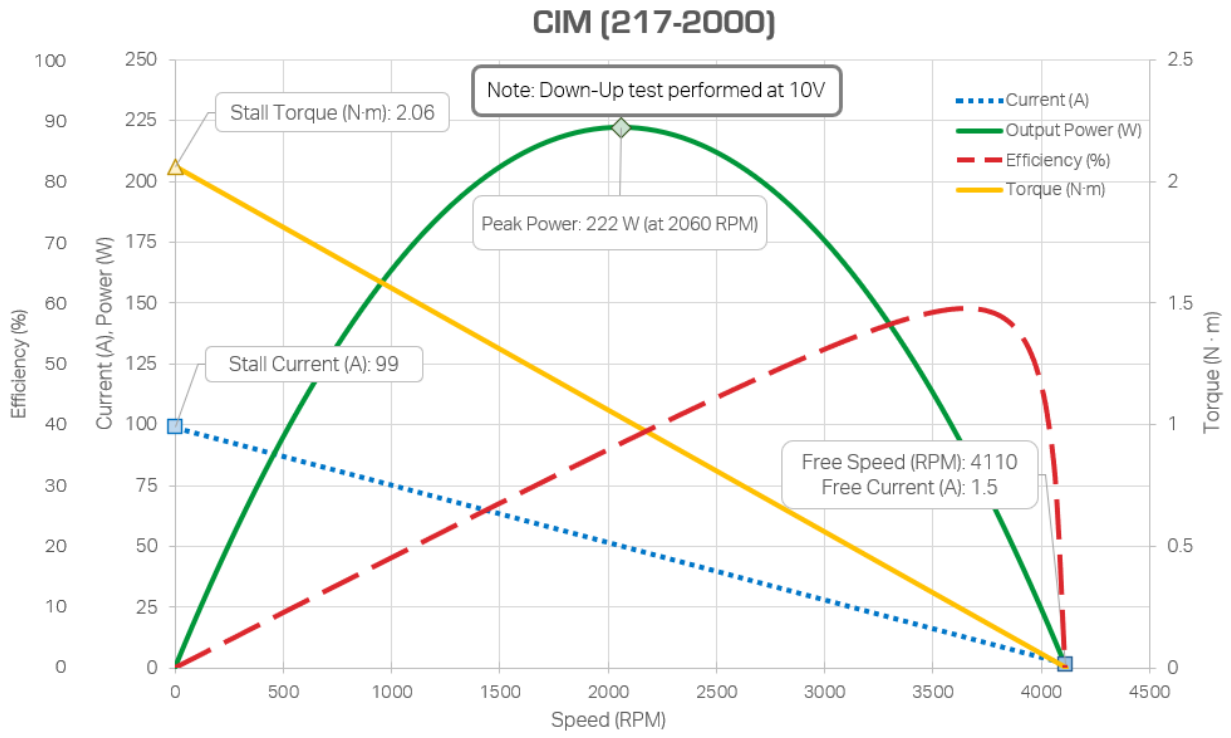


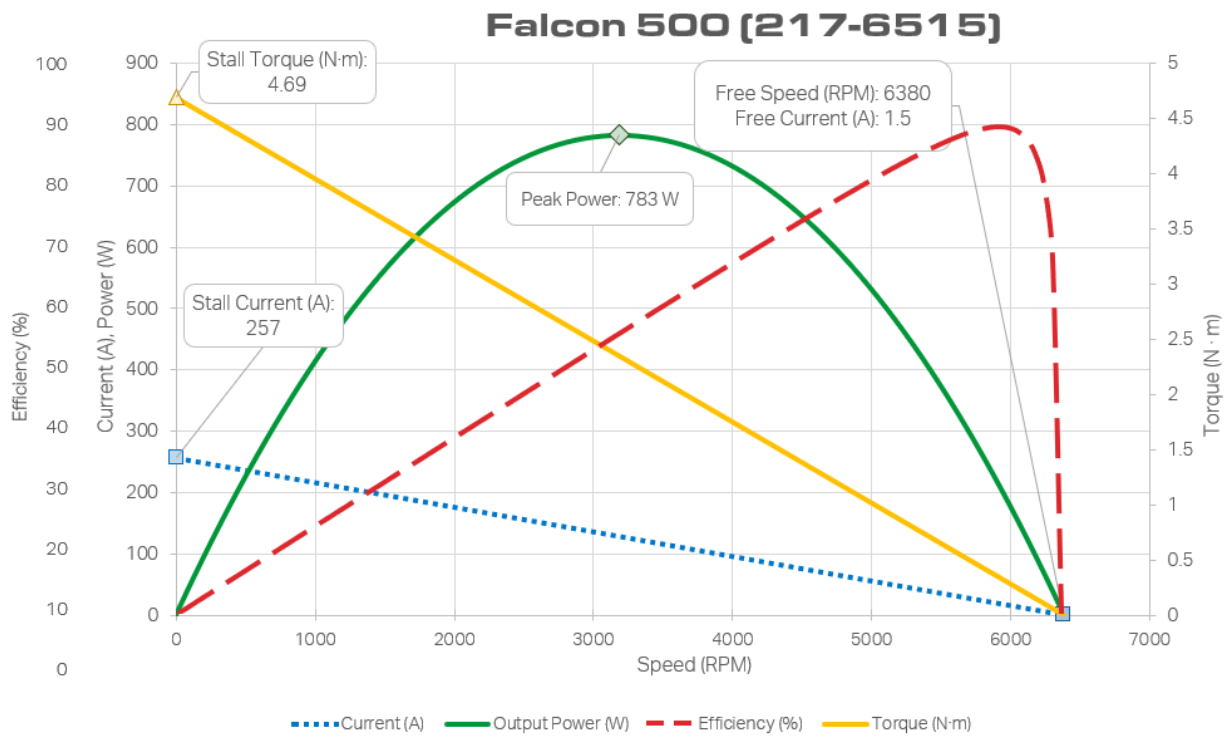
NEO 550 (REV-21-1651)



775pro (217-4347)







Question 5: Torque & Speed

- **Explain the relationship between torque and speed in motors.**

In motors, torque and speed are inverse to one another.

Question 6: Torque, Power, Power, and Speed

- **When you double the number of motors in a mechanism, what happens to:**
  - **Torque**
  - **Power**
  - **Speed**
- **Why?**

When you put double the number of motors in a mechanism, you get twice the torque and consequentially twice the power, but the same speed because acceleration is directly proportional to force.

Question 7: Reduction

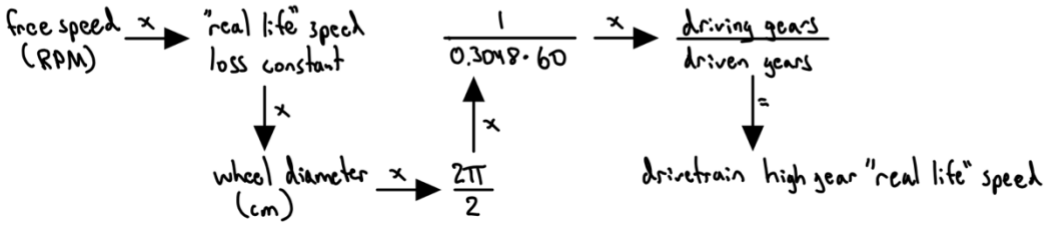
- **Define reduction. How can you achieve reduction in a mechanism?**

Reduction is used to slow a motor down to get more torque. You can achieve reduction in a mechanism by using gears, belts, and chains.

Question 8: Free Speed & Output Speed

- **Create a flowchart for how to convert free speed into output speed with the JVN spreadsheet.**

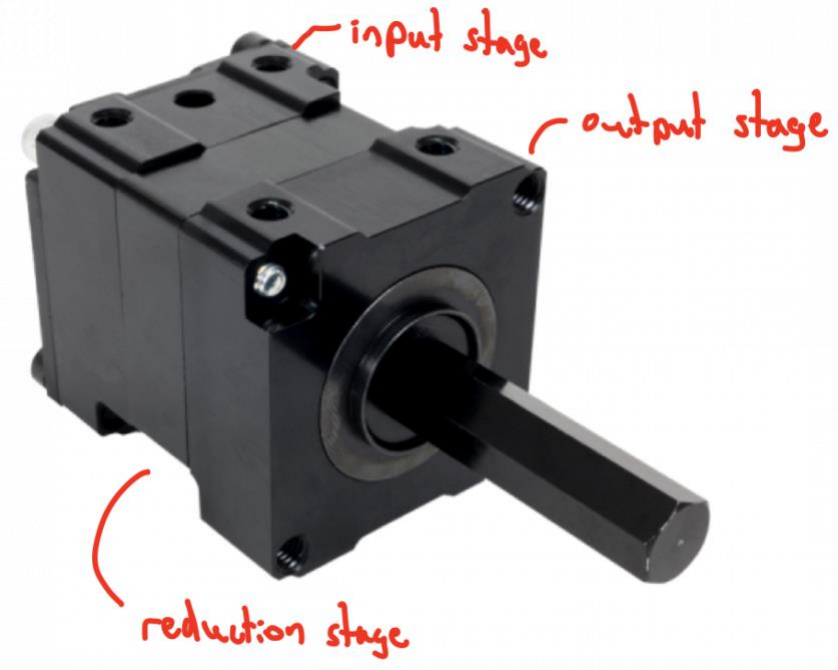
$$\text{free speed (RPM)} \cdot \text{"real life" speed loss constant} \cdot \frac{\frac{\text{wheel diameter (cm)}}{2} \cdot 2\pi}{0.3048 \cdot 60} \cdot \frac{\text{driving gear}_1}{\text{driven gear}_1} \cdot \frac{\text{driving gear}_2}{\text{driven gear}_2} \cdot \frac{\text{driving gear}_2}{\text{driven gear}_3} \cdot \frac{\text{high speed driving gear}}{\text{high speed driven gear}} = \text{drivetrain high gear "real life" speed}$$



Question 9: VersaPlanetary

- **What is a versaplanetary gearbox? Sketch a diagram and label each section of the gearbox.**

A VersaPlanetary gearbox is a gearbox with three basic sections that are assembled together to get various ratios: an input stage, reduction stages, and an output stage.



Question 10: Reduction Stages

- **Where should the highest reduction stage go? Why?**

The highest reduction stage should go nearest to the motor because it experiences the least load there.

Question 11: Versa vs. Ultra vs. AM Sport

- **Compare and contrast the versaplanetary, ultraplanetary and AndyMark Sport gearboxes.**

VersaPlanetary gearboxes are the best gearboxes for prototyping because of large variety of reductions and motors that can be used with them. They are very versatile. UltraPlanetary gearboxes are small and lightweight, but don't offer the same number of ratiosas the VersaPlanetary gearboxes. AndyMark Sport gearboxes are heavier and beefier than the other two options. This gearbox has a single piece housing, which brings structural benefits, but also prototyping downsides with it.

Question 12: Servo Motor

- **What is a servo motor? What kinds of mechanisms are they used for?**

A servo motor is a motor that can only rotate a set number of degrees. They are best used as releases for spring-loaded mechanisms and teams that want to avoid using pneumatics.

Question 14: Bearings

- **What are bearings used for? List the different types of bearing and their uses.**

Bearings support rotating shafts and are used to reduce friction in power transmission, making the transmission more efficient. Radial ball bearings are used to support radial loads on shafts with minimal friction. Thrust bearings support axial loads on shafts. Linear bearings support linear motion mechanisms. Finally, one-way bearings are used to only transmit torque in one direction.

Question 15: Bushings

- **What is a bushing? What are their uses cases?**

Bushings are similar to ball bearings, but do not have any roller elements. They are most useful for low-speed applications but can handle much higher loads.

Question 16: Live & Dead Axles

- **What is a live axle? What is a dead axle?**

A live axle transmits torque through a shaft. A dead axle transmits torque directly to the wheel by a sprocket or gear bolted to the wheel.

Question 17: Torque Transfer Shafts

- **Fill in the table of torque transfer shaft profiles below.**

Type	**Sketch of Profile**	**Common Sizes**	**Vendor**	**Description/Use Cases**
Hex Shaft		1/2" and 3/8”	Assortment	Hexagonal
Thunderhex	 (rounded corners)	1/2" and 3/8”	Only VEXpro	Hexagonal but has round corners: can fit in a round bearing
Round Keyed		8mm	Assortment	Circular with a slot cut into it that a machine key fits into; can be used on shooters
D Profile		6mm	Assortment	Round shaft that is placed on a mill to flatten it; mostly used in FTC
Square		1/4"	VEX	Used by VEX EDR hardware;

				useful for prototyping

Question 18: Gears 101

- **Define "gear." What does "DP" mean? What is "pressure angle?"**

A gear is a rotating wheel with teeth that mesh with another gear to transfer torque. Diametral pitch, or DP, is the ratio of the number of teeth per inch of the gears pitch diameter. A higher DP means finer, smaller teeth. Pressure angle is the angle between the direction the teeth exert a force on each other and the line joining the centers of the two gears. Two meshing gears must have the same pressure angle.

Question 19: Gear Comparisons

- **Compare and contrast different gear types and describe their use cases.**

Spur gears, the most basic types of gears have teeth parallel to the axis of rotation and can only be used on shafts that are parallel. They can be used for many things, including gearboxes. Sector gears are spur gears that are not complete circles and are used for mechanisms that do not need to rotate a full 360 degrees. Bevel gears are conical shaped gears with most of their tips cut off. They are also called crown gears. Worm gears are used to get very high reductions in a compact space and transmit torque between perpendicular shafts. Rack gears are linear bars with teeth that allow for linear motion. They are driven by pinions. Planetary gear sets are used to get very large gear reductions in a very compact space. They are composed of a sun gear at the center of the assembly, which meshes to multiple planet gears, which then mesh to a ring gear.

Question 20: Designing with Gears

- **What variables are most important in gear design? List, define and write equations for center-to-center distance and pitch diameter. Define all variables used.**
- **Define pitch diameter.**

Center to center distance, pitch diameter, and the diametral pitch are the most important in gear design. Center to center distance is the distance from the center of one gear to the center of the other. Pitch diameter is the diameter of the pitch circle. It is also the diameter at the base of the tooth space. Diametral pitch is the number of teeth to the pitch diameter.

Center to center distance:

$$C = \frac{N_1 + N_2}{2P}$$

N_1 = number of teeth on gear 1
N_2 = number of teeth on gear 2
P = diametral pitch of the gears

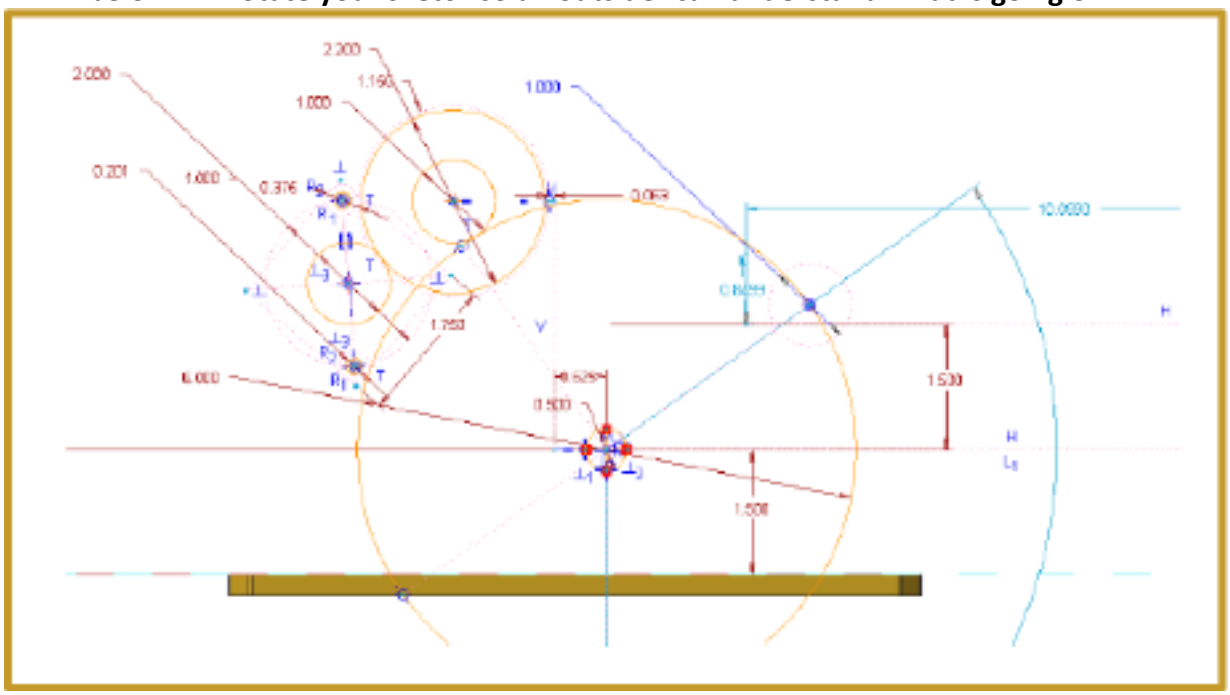
Pitch diameter:

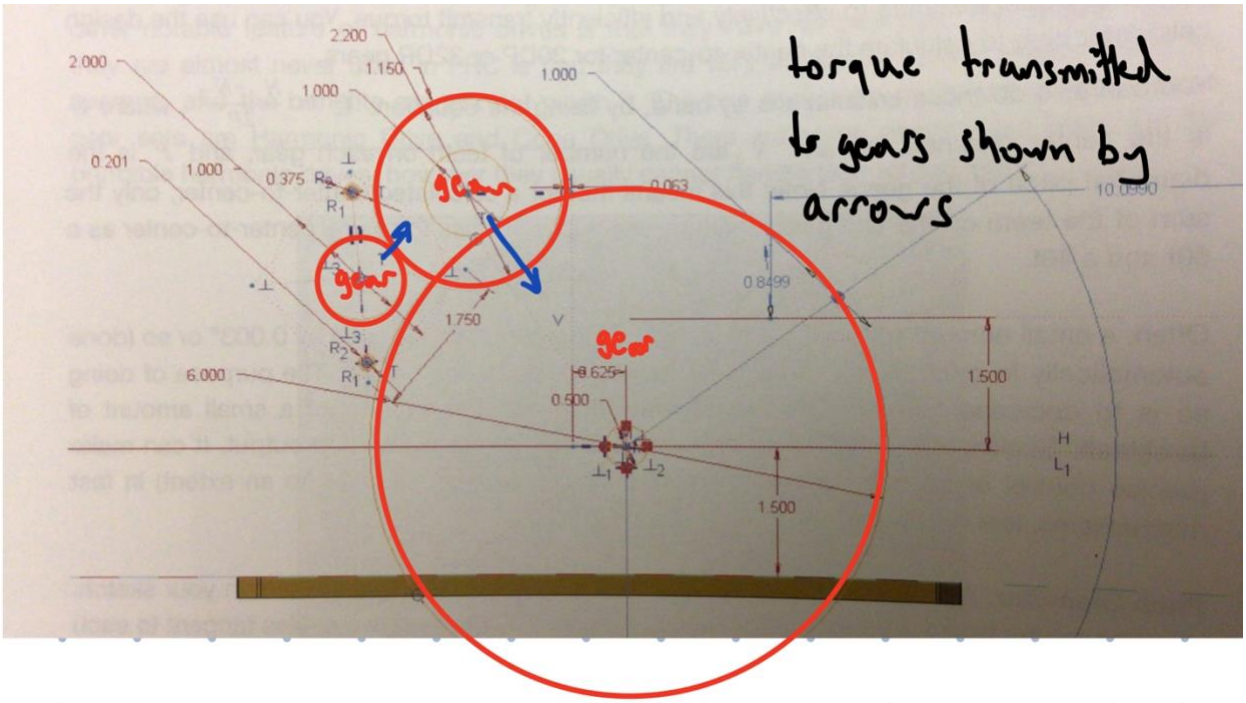
$$P_d = \frac{N}{diametral\ pitch}$$

N = number of teeth

Question 21: 2D Sketch with Gears

- **Label where the gears are located in the annotated sketch excerpt from the manual below. Annotate your sketch so an outsider can understand what is going on.**





Question 22: Chain 101

- **What are the differences between #25, #35 and bike chain?**
- **What are master and half links used for?**

A #25 chain is lighter, while a #35 chain is capable of transferring higher loads. The bicycle chain is lighter and smaller than #25 chain. Master links allow you to connect two ends of a chain run without using a chain tool. It should be avoided on final robots because it is much weaker than normal chain. Half links allow you to create a chain with an odd number of links. They are also weaker than normal chain.

Question 23: Designing with Chain & Sproket

- **What design factors are important for chain and sprocket mechanisms?**
- **Why would you add additional length on your sprocket center to center distance? How much length should you add?**

The center to center distance is important for chain and sprocket mechanisms. You should always use an even number of links as to avoid using half links. You can increase the length of the chain to increase efficiency. For #25 chain, add 0.018” and for #35 chain, add 0.012”.

Question 24: Belt & Pulley

- **When would you use belt and pulley vs chain and sprocket?**

Belts and pulleys are used for lighter torque loads than chains and sprockets.

Question 25: HTD vs. GT2

- **Describe, compare, and contrast HTD and GT2 belts.**

HTD belts have round teeth which allow for higher loads. They have a pitch of 5mm. They are used almost exclusively on drivetrains and other high load applications. GT2 belts also have round teeth which allow for higher loads. They have a pitch of 3mm and typically come in a width of 9mm. They are better for lighter load applications because they are more efficient and lighter in weight.

Question 26: Belt & Pulley Design

- **What factors are key in belt and pulley design?**
- **List, define and write equations for pitch length and pitch diameter. Define all variables used.**

Center to center distance is very important in belt and pulley design. Sometimes, it is more effective to shorten this length by 0.005", especially when using the belt for faster moving mechanisms. The pitch length is the length of the belt at the pitch circle of the pulleys. The pitch diameter is the diameter of the pitch circle of a gear.

$$pitch\ length = pitch * number\ of\ teeth$$

$$pitch\ diameter = (pitch * number\ of\ teeth)/\pi$$

Question 27: Belt Calc's

- **Find pitch length given the following:**
  - **Pitch = 3mm**
  - **Number of teeth = 36**
- **Find pitch diameter given the following:**
  - **Pitch = 5mm**
  - **Number of teeth = 60**

Pitch length = 3*36
Pitch length = 108mm

Pitch diameter = (5*60)/π
Pitch diameter = 95.4929mm

Question 28: Polycord

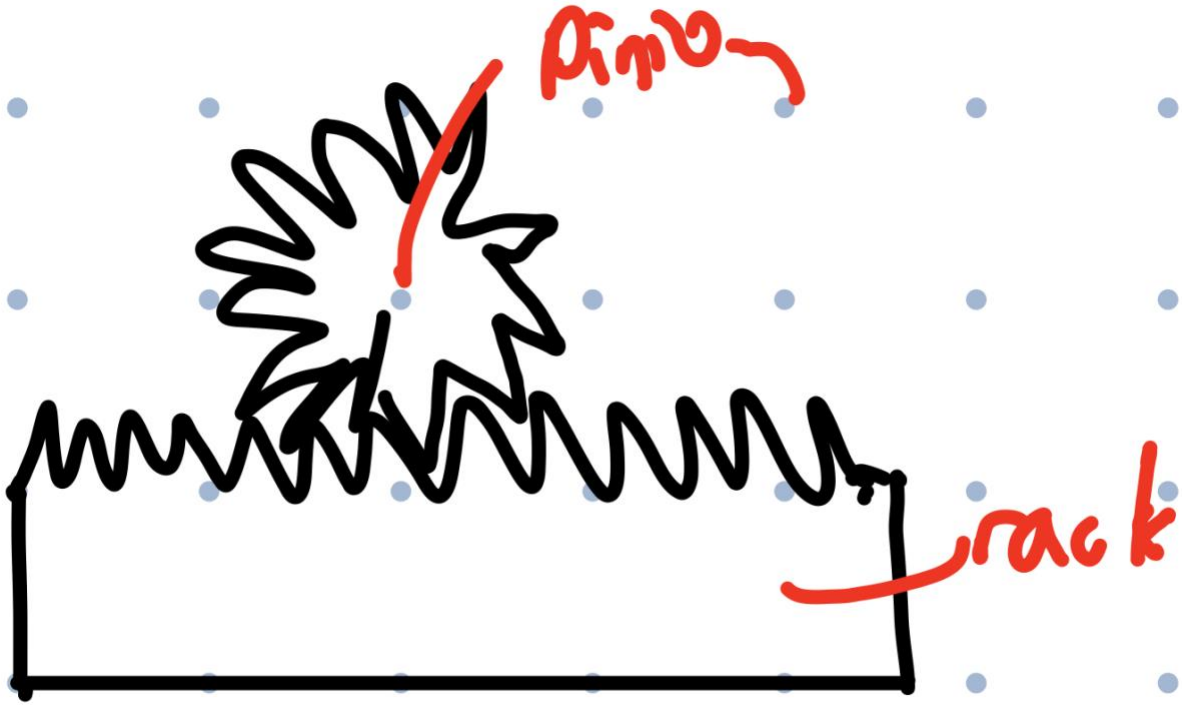
- **What is polycord and what are its use cases? What are the pros and cons of polycord?**

Polycord is a type of tubing made of polyurethane that is used to transmit low torque loads. It is super easy to cut. It acts as a clutch for motors because when stalled, the polycord just slips. Polycord is easy to implement. However, polycord is much less efficient than chains, gears, and belts because of its high friction.

Question 29: Racks & Pinions

- **How does a rack and pinion mechanism work? Create a sketch of a rack and pinion system.**

A pinion is meshed to a rack. If the rack is mounted, when the pinion rotates, the pinion will move along the rack. If the pinion is mounted and the pinion rotates, the rack will move along the pinion moving linearly.



Question 30: Elevators

- **Watch the FRC973 elevator videos**
  - **https://www.youtube.com/watch?v=wZ6a6dc4BGg**
  - **https://www.youtube.com/watch?v=yPG8TGbOqz4**
  - **https://www.youtube.com/watch?v=DJrSkXs-5CE**
- **How are elevators typically driven?**

Elevators are typically driven using either belts, chains, or cables, but they can also be driven with a rack and pinion or lead screws/ball screws.