reading assignment project #3

pg 57-97

by: grace wu

Q1: Brushed and Brushless Motors

Differences between brushed & brushless motors:

Brushed motors are internally commutated while brushless motors are externally commutated. Brushed motors use carbon brushes while brushless motors use magnets. Brushed motors face issues with wear, cleaning by dusting, friction, and heating. Brushless motors are much more efficient and require less maintenance compared to brushed motors and have a longer lifespan because they do not directly contact other parts.

Link to resource:

https://cordlessdrillzone.com/drill-wars/brushless-vs-brushed-motor/

Q2: Motor Specs

List and define the most useful motor specs with units:

1) Speed (measured in RPM, or rotations per minute; rate at which the shaft rotates)
2) Torque (measured in inch-pounds or Newton-meters; amount of rotational force that the motor provides)
3) Peak Power (measured in watts; peak power is the maximum power output a motor can supply and sustain for a short time)

Q3: Motors for Mechanism

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

BAGs, 775 Pros, and 775a RedLines are the best motors for intakes. They are characterized by very high rotational speed and relatively low torque in comparison to drivetrain motors.

Mini-CIMs, CIMs, and REV NEOs are the best motors for drivetrains. They have lower rotational speed and higher torque than intake motors.

Q4: Motor Curves

Watch https://www.youtube.com/watch?v=9UsnLPwEnbw

Explain how motor curves work:

Speed curve: if there is no torque and just the shaft is spinning, the speed will be very high; if there is a lot of torque, then the speed will decrease

Power curve: power is torque times speed, so as the speed linearly decreases as the torque linearly increases, the power curve will become a concave-down quadratic curve that reaches its peak power output at halfway torque and halfway speed (optimization)

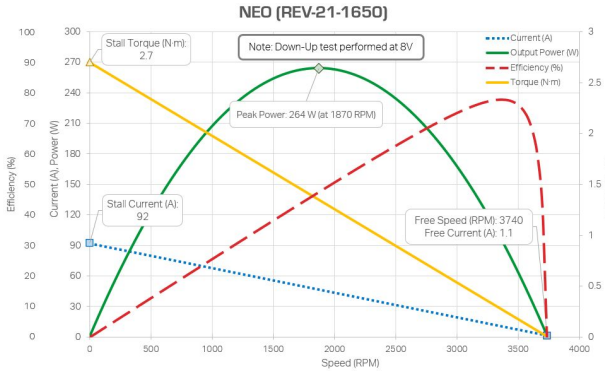
Efficiency curve: when the torque is not causing the motor to produce a lot of heat energy instead of mechanical energy, it is at its peak efficiency; it peaks towards a lower amount of torque

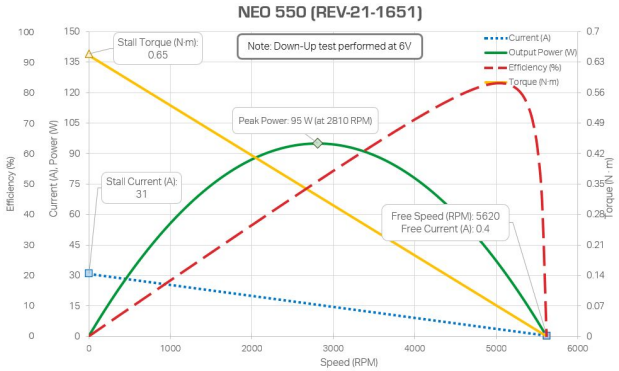
Current curve: the current curve linearly increases as the torque increases; when current is multiplied by voltage, it creates an electrical power curve that is always greater than the mechanical power curve (some power must be lost)

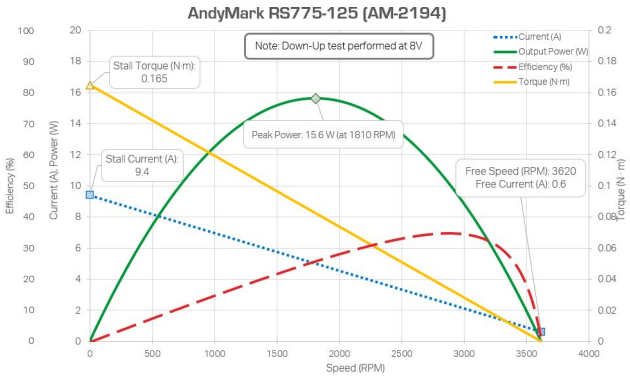
Q4 Continued:

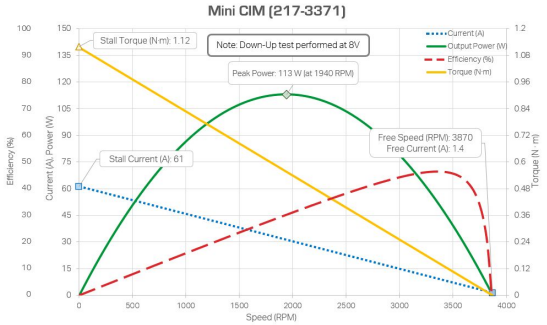
I could only find speed-based motor curves.

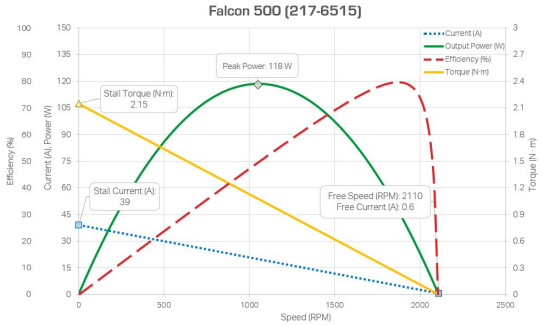
Paste images of the motor curves for a NEO, NEO550, RS775 Pro, CIM, and a Falcon 500











Q5: Torque & Speed

Explain the relationship between torque and speed in motors:

Torque and speed are inversely proportional (speed = power/torque and torque = power/speed). This is because as torque increases (when more load is put on the system), speed tends to decrease. Likewise, when torque decreases (lighter or no load), speed increases. This is why in motor curves, there is a peak in speed when torque is zero.

Q6: Torque, Power, and Speed

When the number of motors in a mechanism is doubled, what happens to...

torque (and why)?

When the number of motors in a mechanism is doubled, the total torque would double because two motors can handle twice the load as one motor.

speed (and why)?

No matter how many motors are used in the mechanism, the speed can't double because motors have a maximum speed.

power (and why)?

Power would double as well because it is the product of torque and speed; because torque doubles but speed stays the same, the power doubles.

Q7: Reduction

Define reduction:

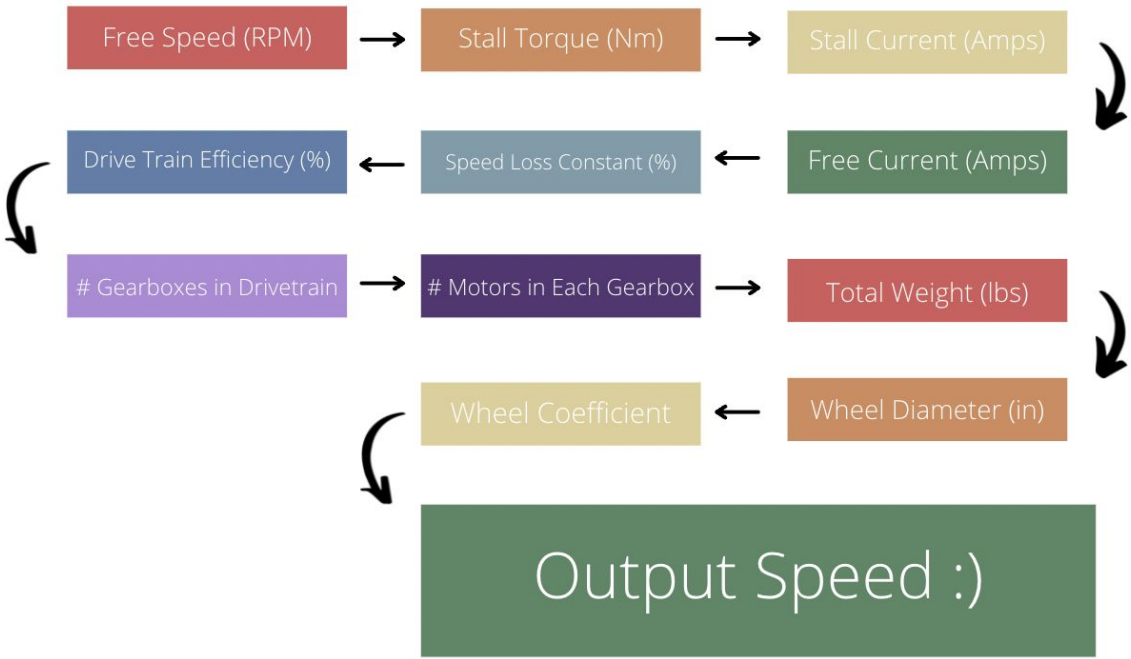
Reduction is a way to slow down your motors because they often operate more quickly than necessary for your mechanism. Methods of reduction consequently produce additional torque.

How can you achieve reduction in a mechanism?

Reduction can be achieved through gears, belts, chains, etc. For example, reduction can be achieved with gears when the gear ratio is greater than 1:1 (greater when a smaller gear drives a larger gear).

Q8: Free Speed & Output Speed

Create a flowchart for how to convert free speed into output speed with the JVN spreadsheet:

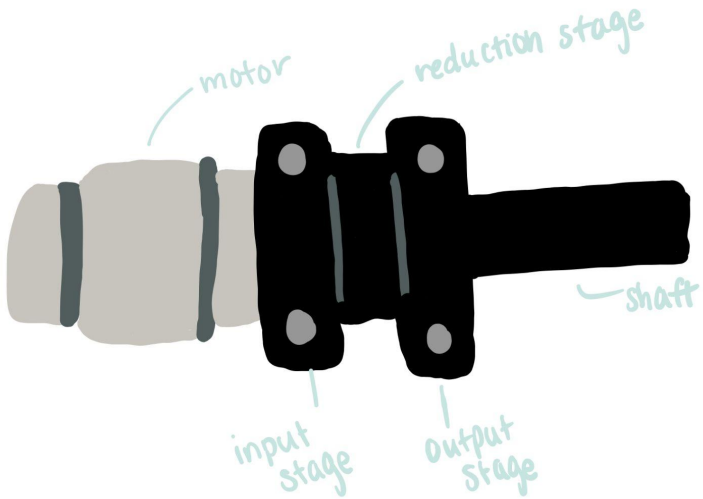


Q9: VersaPlanetary

What is a VersaPlanetary gearbox:

The VersaPlanetary gearbox is a method of getting reduction in an FRC motor. Essentially, a motor is connected to the gearbox that has three different stages (input stage, reduction stage, and output stage). There are different motor sizes, ratios, and output shafts which makes them versatile.

Sketch a diagram and label each section:



Q10: Reduction Stages

Where should the highest reduction stage go and why?

The highest reduction stage should go closest to the motor because that is where it will experience the least amount of load.

Q11: Versa vs Ultra vs AM Sport

Compare and contrast the VersaPlanetary, UltraPlanetary and AndyMarkSport gearboxes:

VersaPlanetary gearboxes are very versatile and can handle greater loads than the UltraPlanetary gearboxes. UltraPlanetary are very small and lightweight and less versatile than VersaPlanetary gearboxes, though there is an option of mounting the gearbox from the face of the output cartridge instead of using the 5 mm hex output. AndyMarkSport gearboxes are the opposite. They are heavier and more sizeable than the other gearboxes, and they structurally use single piece housing, sacrificing a degree of versatility.

Q12: Servo Motor

What is a Servo Motor?

Servo Motors are motors that can only rotate a set number of degrees but can rotate continuously. They have little torque in comparison to most motors but can be used for small actuations.

What kind of mechanisms are Servo Motors used for?

Servo motors are used in mechanisms that require precise and quick movements. For example, servo motors are used in CNC machines, printers, camera auto-focuses, etc.

Q13: Bearings

What are bearings used for?

Bearings are used to support rotating shafts and reduce friction in apparatuses that transmit power.

List the different types of bearings and their uses:

Radial Ball Bearings: support radial loads on shafts and minimize friction; load acts perpendicular to direction of motion; often used for mechanisms with low to moderate RPM

Thrust Bearings: support axial loads; loads act parallel to direction of motion; frequently used in swerve drives

Linear Bearings: support linear motion mechanisms; frequently used in elevators; certain types of linear bearings are also used on machine tools, such as CNC routers

Q14: Bushings

What is a bushing?

Bushings are inserts that are often made of plastic or bronze. They are similar to bearings, but they have no rolling aspect and have more friction than bearings. They can also handle much higher loads and are lighter and cheaper than bearings.

What are their use cases?

Bushings are more frequently used for low-speed mechanisms. They can be used to limit a hole size and resist abrasion. Some bushings can be used to insulate voltage applications as well.

Q15: Live & Dead Axles

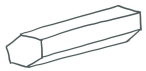
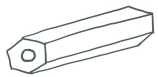
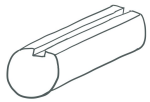
What are live axles?

Live axles transmit torque through the shaft to the wheel, gear, or sprocket and rotates the shaft. Live axles laterally (parallelly) connect wheels or gears. Live axles are attached

What are dead axles?

Dead axles are characterized by bearings that are inside of wheel, gears, or sprockets. Torque is transferred directly to the wheel by a sprocket or gear that is attached to the wheel. Dead axles can be used as standoffs and the shaft does not rotate.

Q16: Torque Transfer Shafts

Type	Sketch of Profile	Common Sizes	Vendor	Description/Use Cases
Hex Shaft		⅜” and ½”	McMaster-Carr REV Robotics	Often used for power transmission applications; robotics conveyor systems
Thunderhex		⅜” and ½”	Only sold by VEXpro	Frequently used to connect wheels and rollers in FRC robots
Round Keyed		⅜”, ½”, ¾”, 1”	McMaster-Carr	Rarely used in FRC now; used to connect a rotating machine element to a shaft
D Profile		6 mm	McMaster-Carr Modern Robotics Inc	Mostly used for VersaPlanetary and VersaHex adapters; not commonly used on FRC robots
Square		⅛” and ¼”	McMaster-Carr	More commonly used in VEX, connected to motors

Q17: Gear 101

Define gears?

Gears are rotating wheels with teeth that mesh to transfer torque. They can used to reduce and increase speed (increase and decrease torque, respectively). Meshing gears rotate in opposite directions.

What does “DP” mean?

DP stands for “Diametral Pitch”, or the ratio of the number of teeth per inch of the gear pitch diameter. A higher DP represents more fine & smaller teeth in each inch of pitch diameter.

Common in FRC:

- 20 DP
- 32 DP

What is “pressure angle”?

The pressure angle is the angle between the direction of the teeth as they exert force on each other when meshing and the line extended from the center of the two gears. Meshing gears must have the same pressure angle.

Common in FRC:

- 14.5 degrees
- 20 degrees

Q18: Gear Comparisons

Compare and contrast different gear types and their use cases:

Spur gears are gears that have teeth that are parallel to the rotational axis; they are used on parallel shafts, particularly when manufacturing gearboxes

Sector gears are not complete circles; they are used on mechanisms that do not need to rotate 360 degrees, particularly on shooter pivots and arms

Bevel gears are conical with their tip cut off (like a frustum); they are used to transfer torque between shafts

Worm gears are used to get high reductions in small spaces and can transmit torque between perpendicular shafts; they look like screws and allow mechanisms to self-lock and hold their positions

Rack gears are linear bars with teeth that allow linear motion and are driven by pinions (circular motion)

[I did not discuss gearboxes because they were already mentioned in a previous slide].

Q19: Designing with Gears

Which variables are most important in gear design?

1) Two meshing gears must have the same pressure angle and diametral pitch
2) The teeth count of meshing gears changes the gear ratio (and reduction of torque, when applicable)
3) Center-to-center distance changes how efficiently torque is transmitted
4) Pitch diameter allows you to effectively make sketch designs
5) Backlash is the dead spot between the input and output; impacts precision

List, define, and write equations for center to center distance and pitch diameter:

Center to Center:

$C = (N_1 + N_2) / 2P$; sum of the number of teeth on the two gears divided by twice the diametral pitch of the gears equals the center distance

Pitch Diameter:

$P_d = N / D_p$; the number of teeth divided by the diametral pitch equals the pitch diameter

Define all variables used:

C = Center Distance; $N_1 + N_2$ are the number of teeth on the gears; P is the diametral pitch of the gears

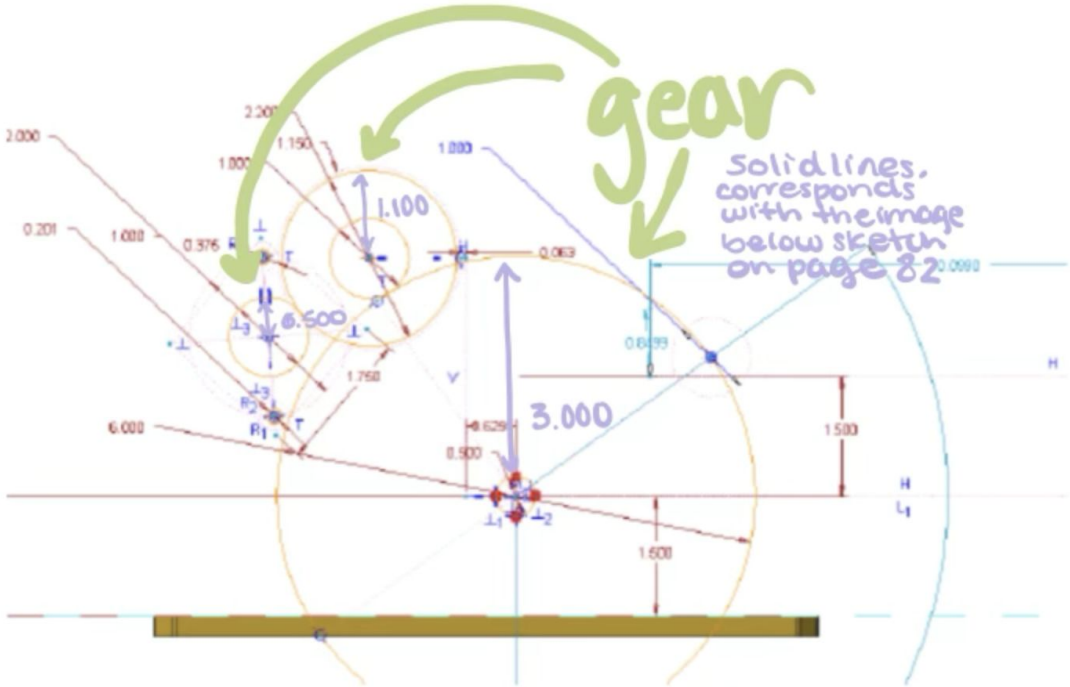
P_d = Pitch Diameter; N is the number of teeth on the gear; D_p is the diametral pitch

Define pitch diameter:

Pitch diameter is essentially the length across the entire gear (similar to the diameter of the circle). Diametral pitch is basically the number of teeth divided by the pitch diameter.

Q20: 2D Sketches with Gears

Label where the gears are located in the annotated sketch excerpt. Annotate thoroughly.



Q21: Chain 101

What are the differences between a #25, #35, and a bike chain?

#25 chains are the most common in robotics. Each link is .25 (¼) inches long. It is commonly used on drivetrains.

#35 chains are larger, heavier, and stronger than #25 chains. Each link is 0.375 (⅜) inches long.

Bike chains are stronger but more narrow than #25 chains. They are not as commonly used, however, because the pitch is 0.5 (½) inches, and sprockets with shaft bores are typically not made in that size.

What are master and half links used for?

Master and half links are used for connecting the two ends of a chain without using a chain tool. Half links are specifically used for an odd number of links. Master and half links are not strong and can break your chain runs, so it is better to use chain breaks for more permanent mechanisms.

Q22: Designing with Chain & Sprocket

What design factors are important for chain & sprocket mechanisms?

1) Center to center distance affects the transmission of torque
2) Number of links should be even so that there are no half links (half links are weak and may break under high loads)
3) Type of chain (can bear different load sizes)
4) Sprocket size

Why would you add length on your sprocket center to center distance?

You would want to add length to your center to center distance if the chain link count was odd and you need it to be even; it also can make chains run more efficiently and effectively.

How much length should you add?

For #25 chains, it is best to add around 0.018”. For 35” chains, the add length is typically around 0.012”.

Q23: Belt & Pulley

When would you use a belt & pulley vs chain & sprocket?

A belt and pulley system consists of a number of pulleys connected by a flexible belt while a chain and sprocket system consists of a number of sprockets connected by a linked chain. Belts are usually used to transmit lighter torque loads. Belts can transmit equal amounts of torque as chains, but such belts would be much thicker and heavier than respective chains.

Q24: HTD vs GT2

Describe, compare, and contrast HTD and GT2 belts:

HTD (5mm) and GT2 (3mm) belts both have rounded teeth that permit them to carry a higher load (high torque capabilities). However, GT2 belts are typically used for lighter loads and are smaller, more efficient, and more lightweight than HTD belts.

Q25: Belt & Pulley Design

What factors are key in belt and pulley design?

1) Center to center distance is vital for torque transmission
2) Type of belt can affect torque transmission and load capacity
3) Pulley sizes; affects speed

List, define, and write equations for pitch length and diameter:

Pitch Length:

P * N = Pitch Length; the pitch multiplied by the number of teeth in the gear equals the pitch length

Pitch Diameter:

(P * N) / pi = Pitch Diameter; the quantity of the pitch multiplied by the number of teeth in the gear divided by pi equals the pitch diameter (makes sense because circumference divided by pi equals diameter)

Define all variables used:

P = pitch (ratio of total number of teeth to pitch diameter; expressed in teeth per inch)

N = number of teeth in gear

Q26: Belt Calculations

Find the pitch length given pitch = 3mm and number teeth = 36:

Pitch Length = Pitch * Number of Teeth

Thus: 3mm * 36 ⇒ Pitch Length : 108

Find the pitch diameter given pitch = 5mm and number teeth = 60:

Pitch Diameter = (Pitch * Number of Teeth) / π

Thus: (5mm * 60) / π = 300/π ⇒

Pitch Diameter : 95.493

Q27: Polycord

What is polycord and what are its use case?

Polycord, also known as eagle tubing, is a tubing that transmits light torque loads. It is made from polyurethane and is less efficient than timing belts, gears, or chains.

What are the pros and cons of polycord?

Pros:

- Can be cut to any length (should be 10% shorter than the desired length to transmit the torque properly)
- Easiest method to design for torque transmission

Cons:

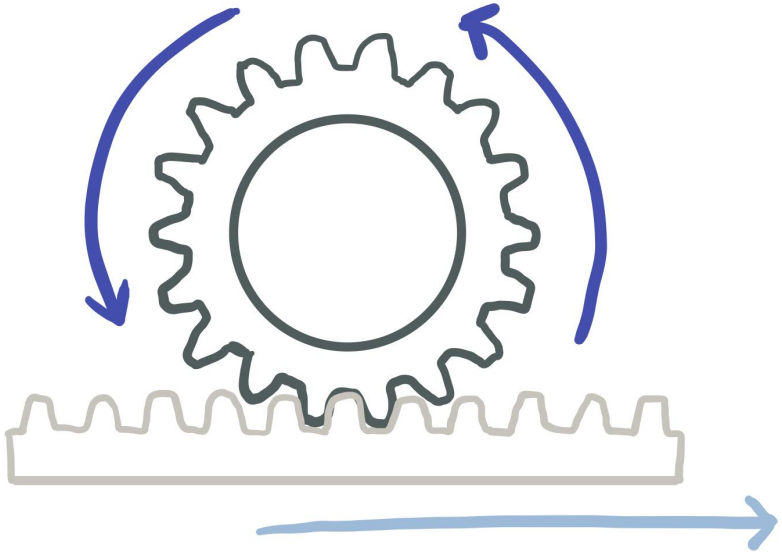
- Least efficient method of transmitting torque when compared to timing belts, gears, and chains
- Have a lot of drag torque

Q28: Racks & Pinions

How does a rack & pinion mechanism work?

The pinion, a circular gear, and a rack, a linear gear. The rack & pinion mechanism converts a circular motion into linear motion and are often used in transportation vehicles (cars, train railways, etc).

Create a sketch of a rack and pinion system:



Q29: Elevators

Watch:

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?

Linear elevators are typically driven using some sort of belt, chain, or cable, though rack & pinions and lead screws/ball screws are also used quite frequently. The vertical linear movement from these parts allows the platform to raise and lower.