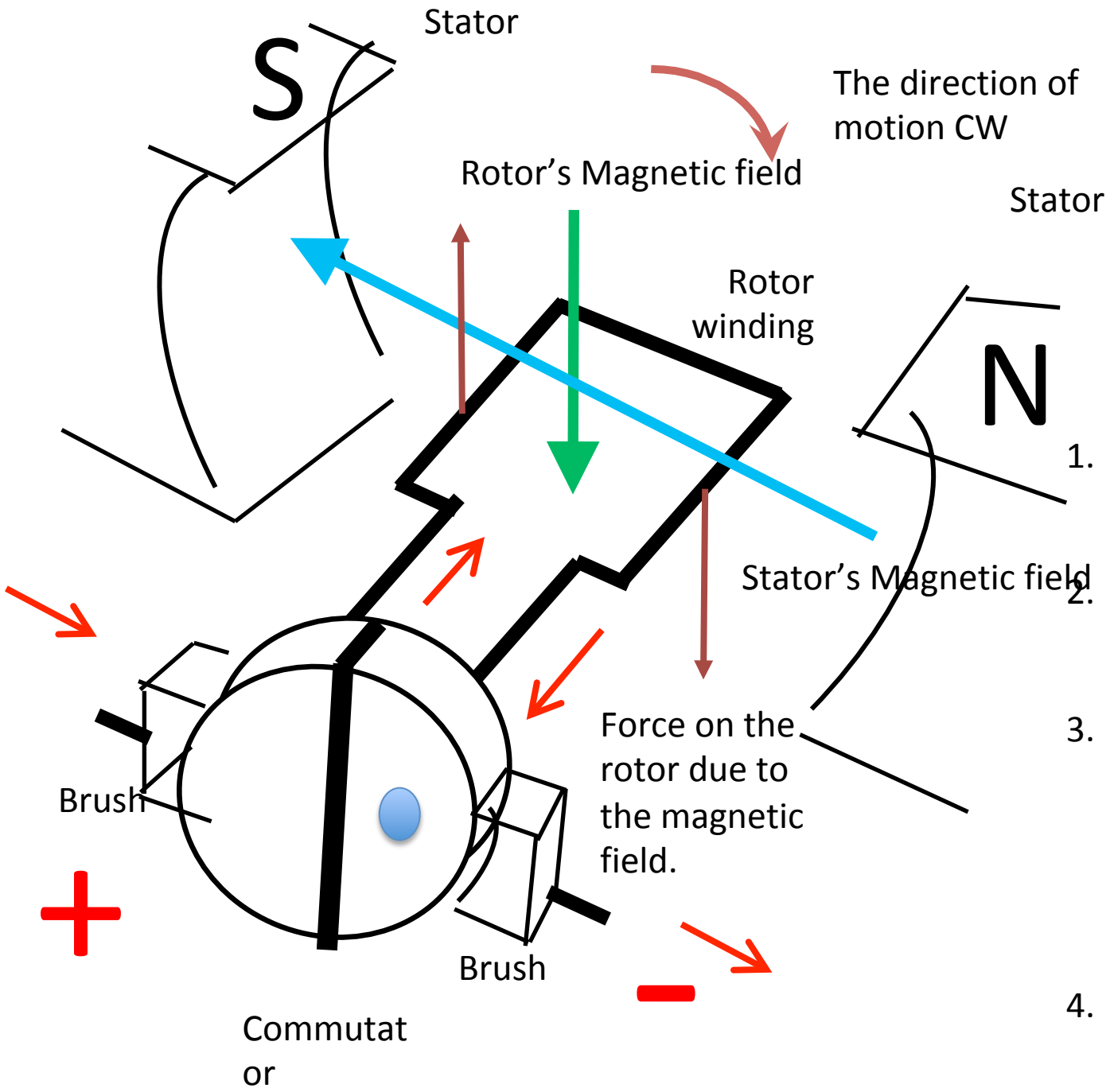
DC MOTOR PRINCIPLES

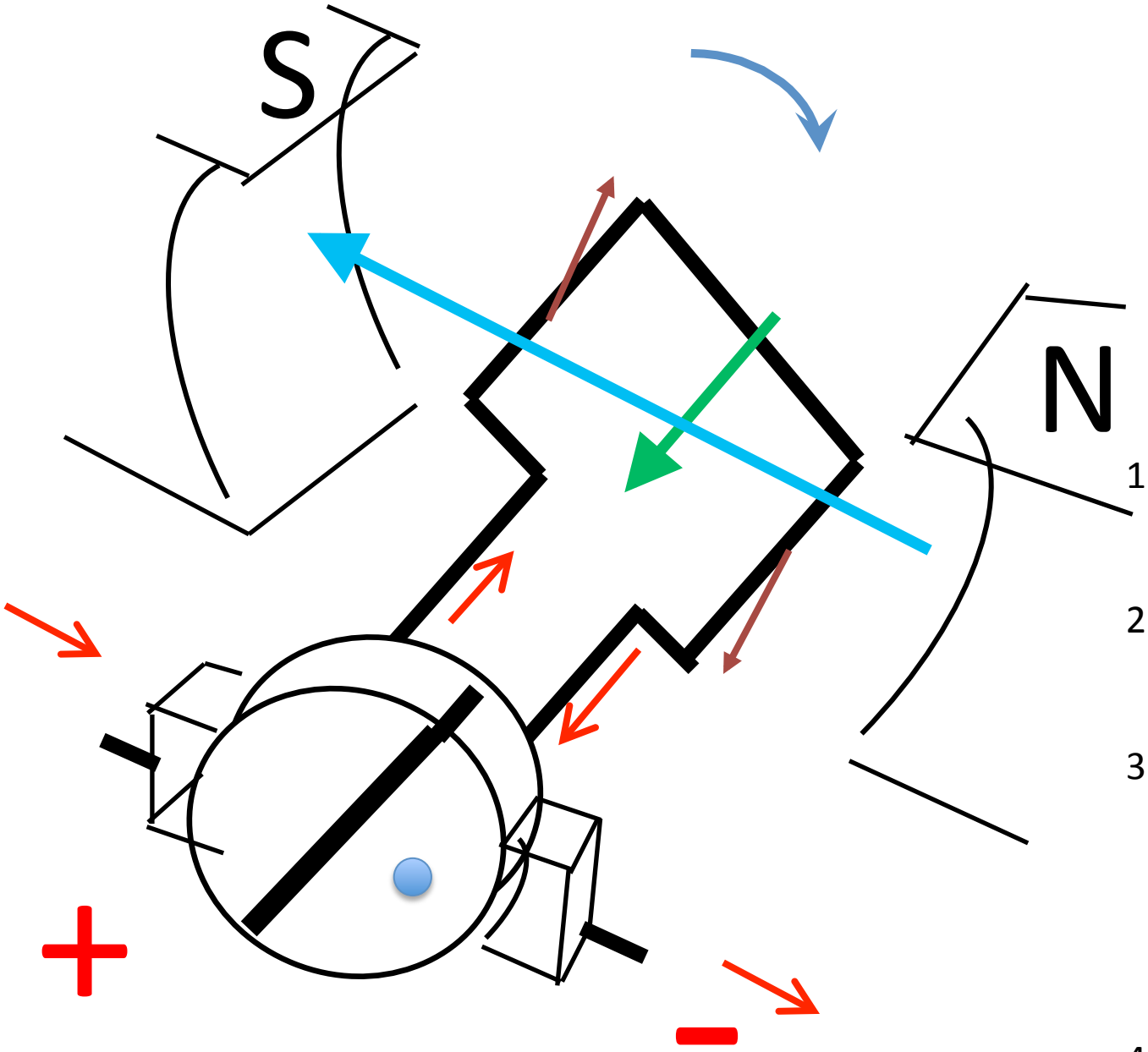
Lecture 15

Basic DC Motors

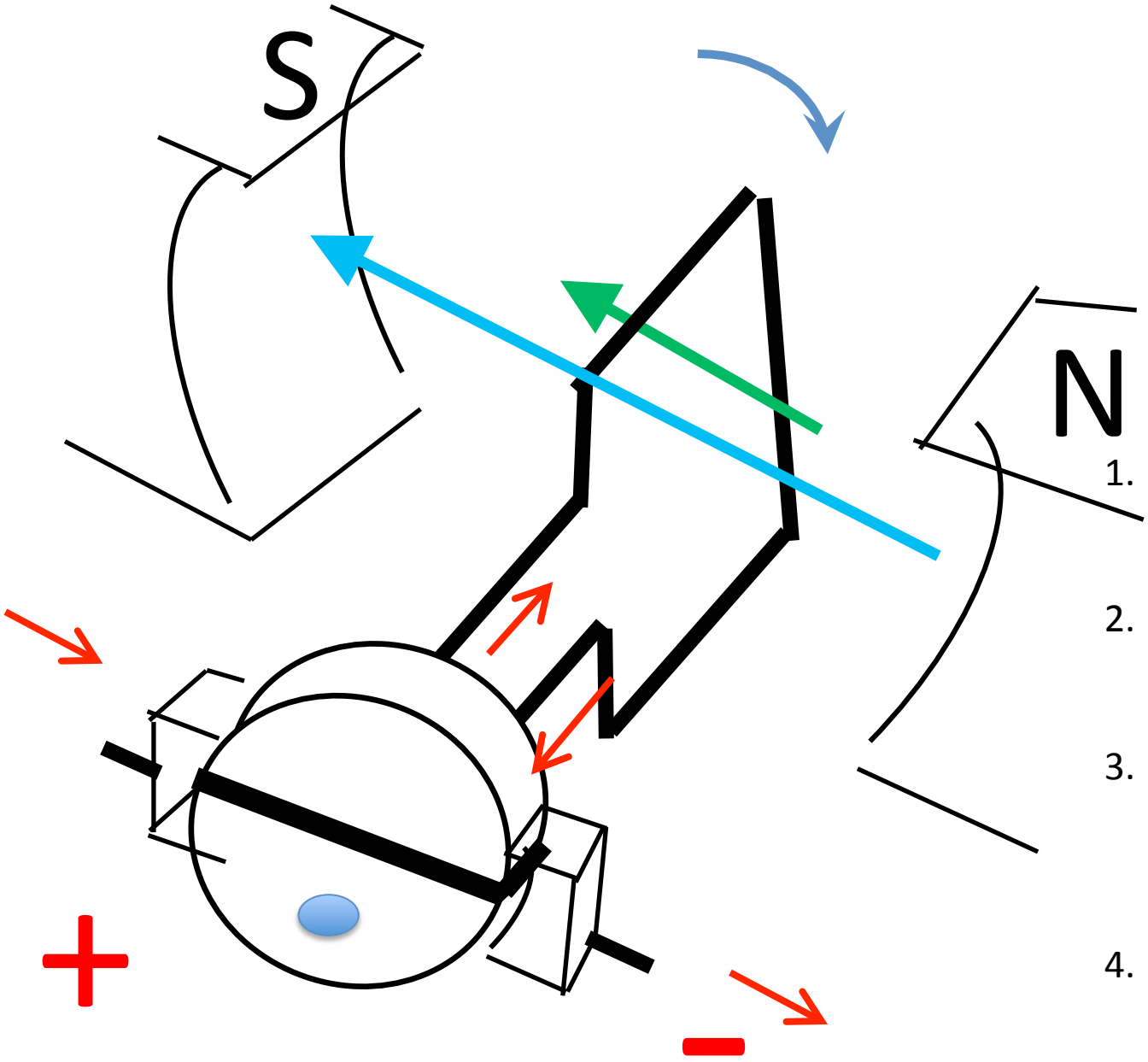
- The most simplest DC motor has a stationary set of magnetic poles. This is called the stator. The stator can use permanent magnets or electro-magnets which creates a stationary magnetic field. The stator can have multiple magnetic fields.
- The DC motor has a rotating set of electro-magnetic poles called the rotor. A DC voltage is applied to the rotor through a set of terminals called brushes. The brushes are attached to a rotating device called a commutator which feeds the rotor winding(s) that create the rotor's electro-magnetic field(s).
- The commutator is designed to switch the direction of the current in the rotor windings to cause the rotor magnetic fields to be out of phase with the stator's magnetic field(s).



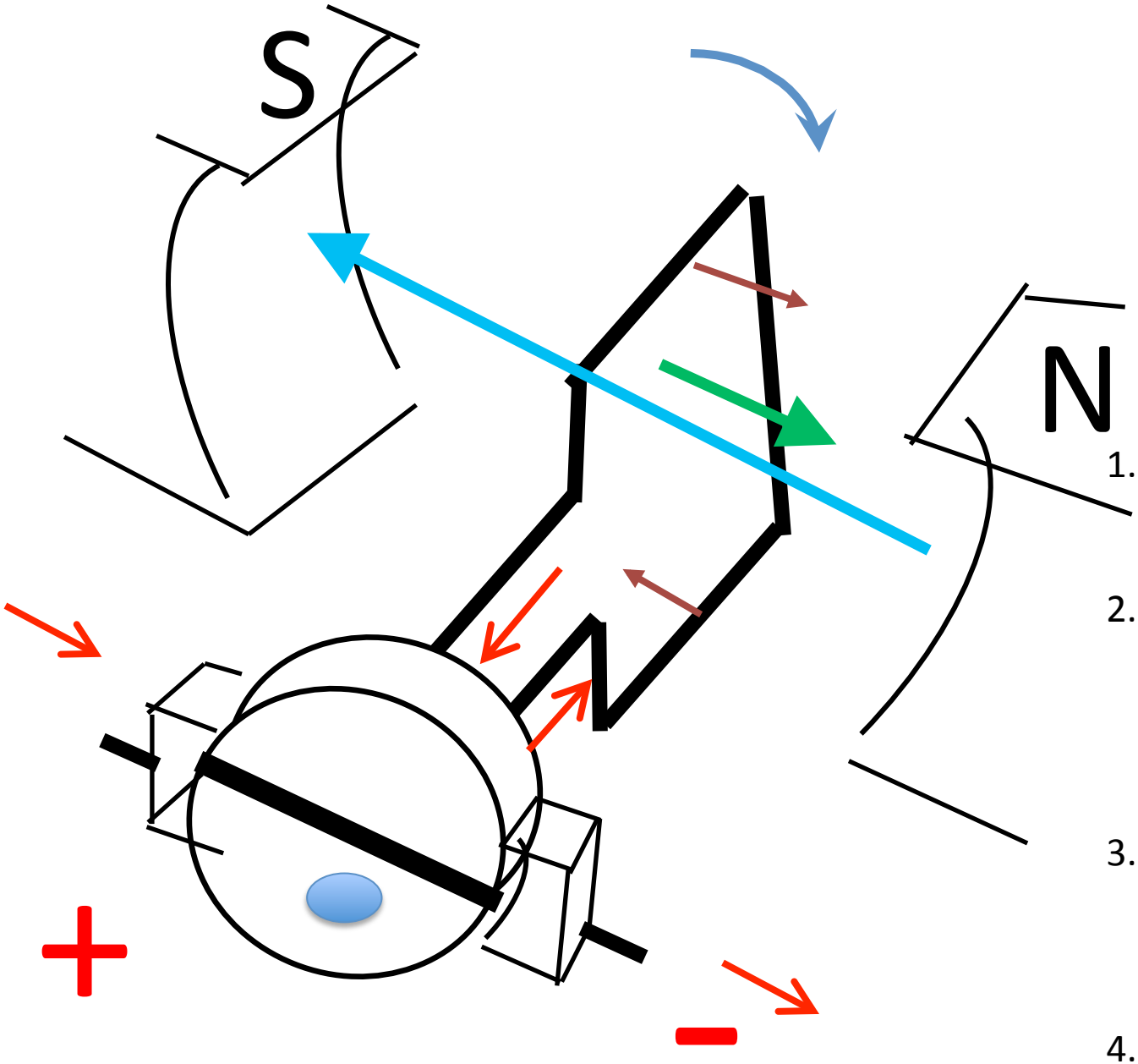
1. The magnetic field of the stator goes from N to S.
2. The commutator gap is perpendicular to the brushes
3. The current flowing through the rotor loop caused the perpendicular magnetic field to point downward.
4. There is now a force on the rotor to align the rotor's magnetic



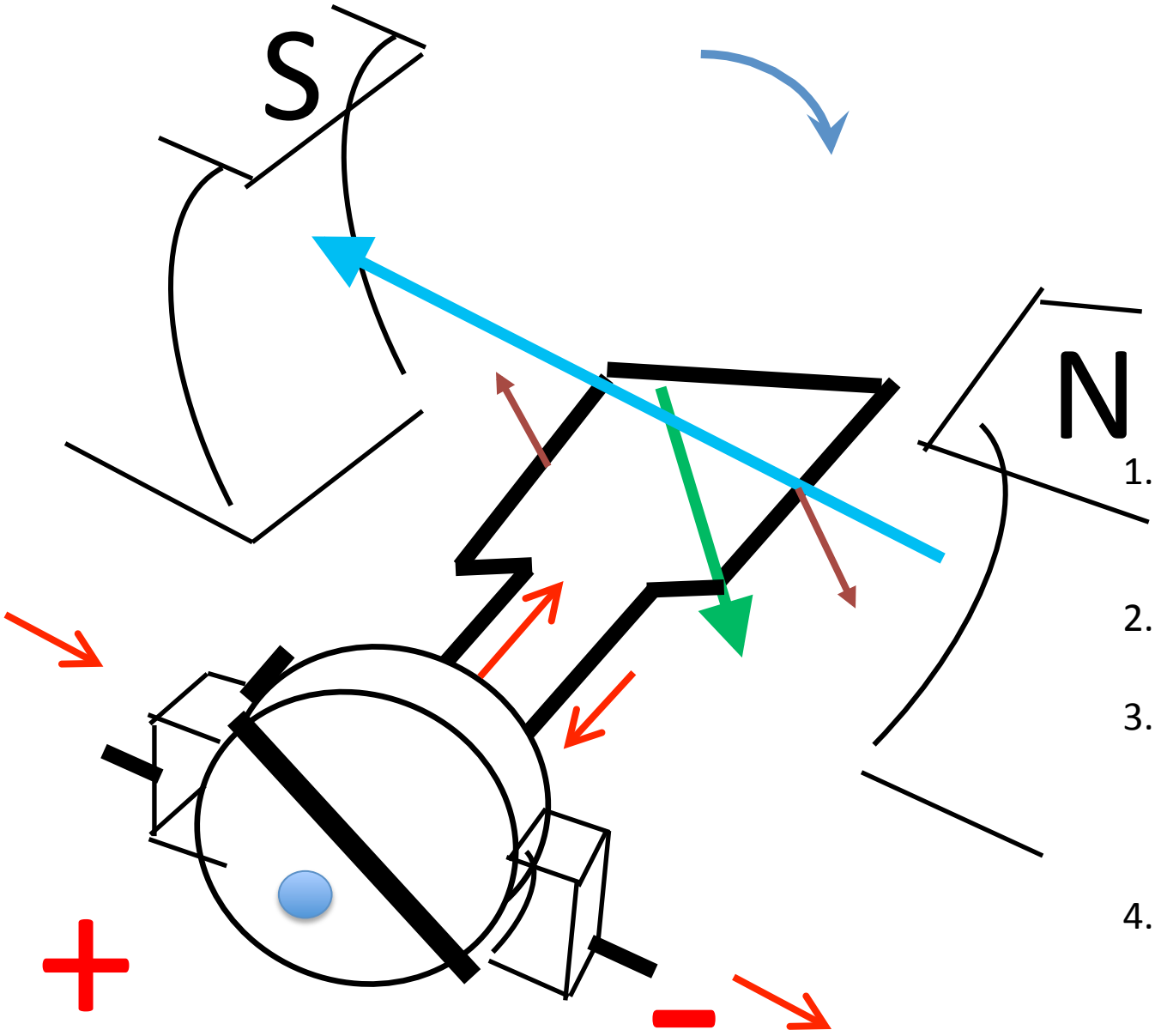
1. The magnetic field of the stator goes from N to S.
2. The commutator gap is at angle to the brushes
3. The current flowing through the rotor loop caused the perpendicular magnetic field to point downward.
4. The force on the rotor to align the magnetic fields is



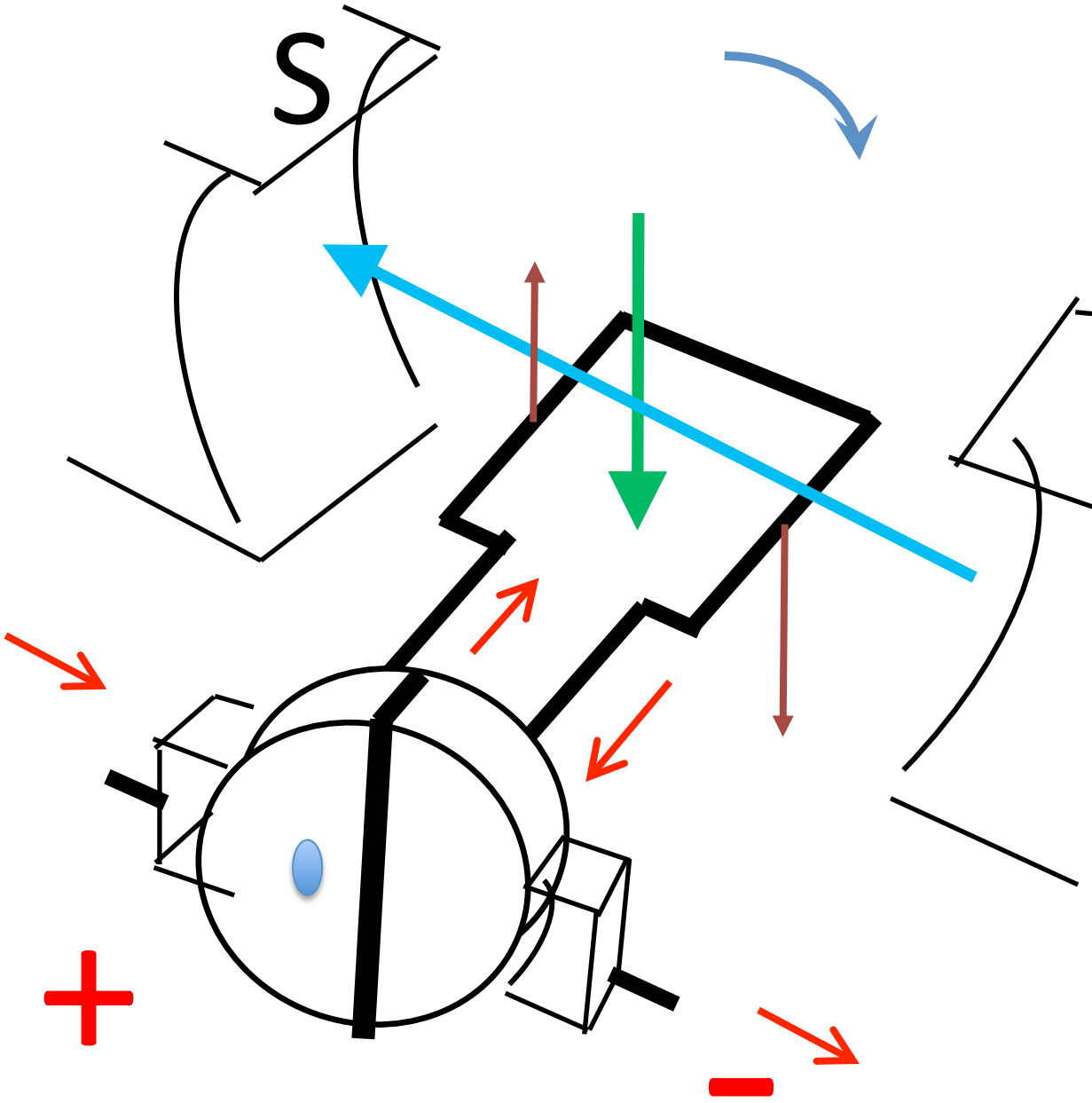
1. The magnetic field of the stator goes from N to S.
2. The commutator gap is aligned with the brushes.
3. The rotor magnetic field is aligned with the stator magnetic field.
4. The force on the rotor to align the magnetic fields is zero.
5. The direction of



1. The magnetic field of the stator goes from N to S.
2. The momentum of the rotor causes commutator gap reverse the current in the rotor.
3. The rotor magnetic field is now opposite to the stator magnetic field.
4. The force on the rotor reappears to align the magnetic



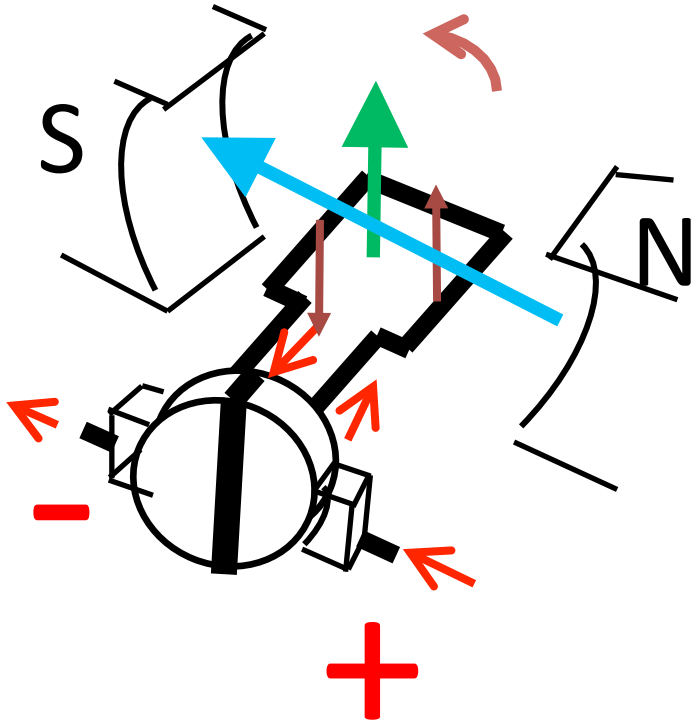
1. The magnetic field of the stator goes from N to S.
2. The rotor continues to rotate CW.
3. The rotor magnetic field is moving to align with the stator magnetic field.
4. The force on the rotor continues to align the magnetic fields.
5. The direction of motion is CW.



1. The magnetic field of the stator goes from N to S.
2. The rotor continues to rotate CW and has moved 180 degrees.
3. The rotor magnetic field is moving to align with the stator magnetic field.
4. The force on the rotor continues to align the magnetic fields.
5. The direction of

Some properties of DC motors

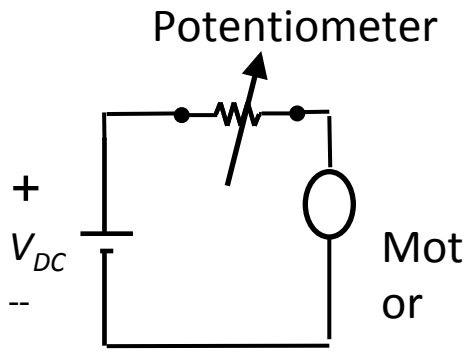
- Reversing the direction of the motor can be achieved by reversing the polarity of the DC supply voltage.

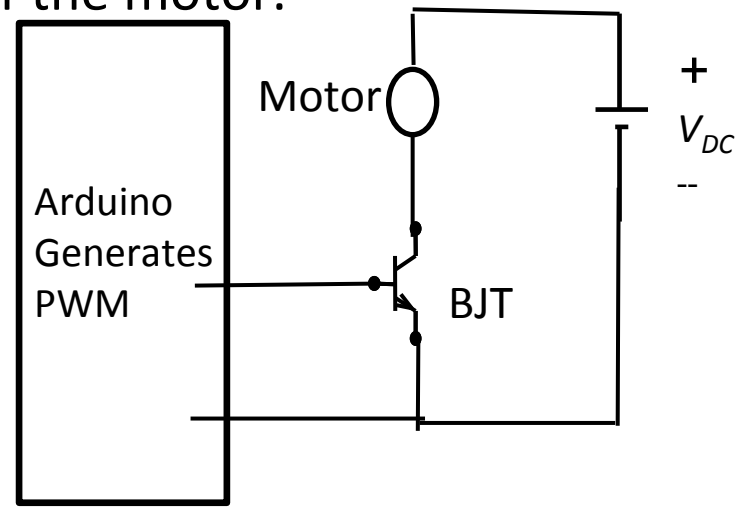


- The speed of rotation is a function of the current and therefore the DC supply voltage.

Speed Control

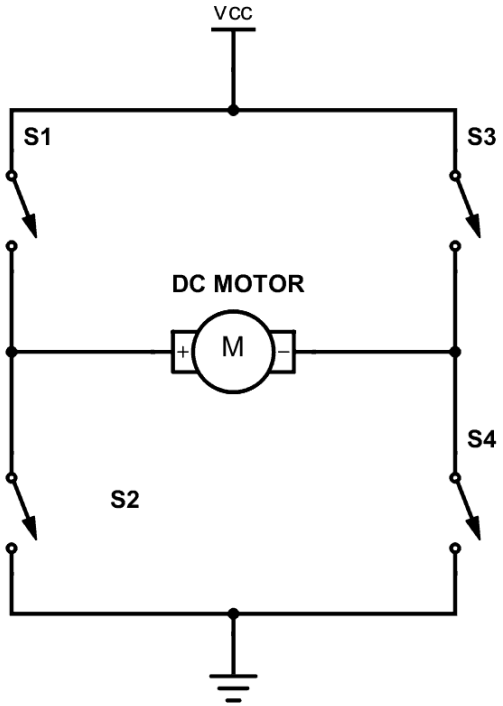
- By placing a potentiometer in series with the motor and DC supply, a varying current and therefore, varying speed can be achieved.
- However, consumes a lot of power. Instead, Pulse Width Modulation (PWM) can be used. The Arduino and a transistor can be used to control the speed of the motor.

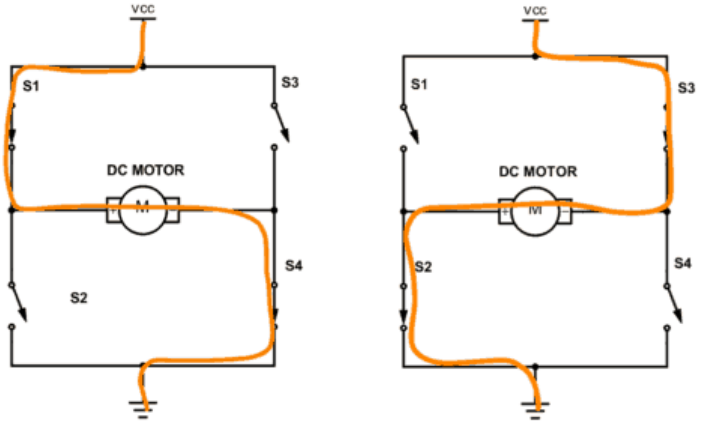




- Third party speed controllers can also be procured.

Reversing the direction of rotation
How an H-Bridge works



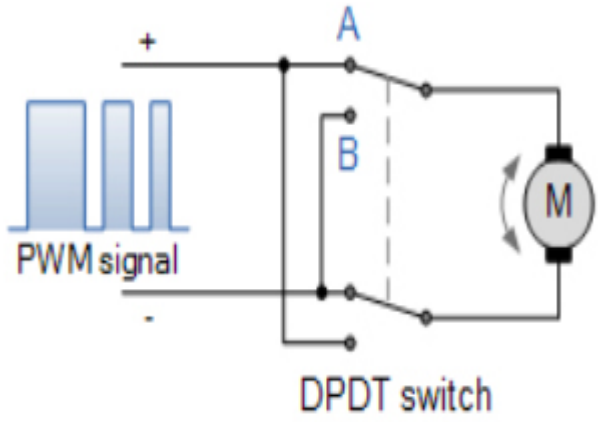


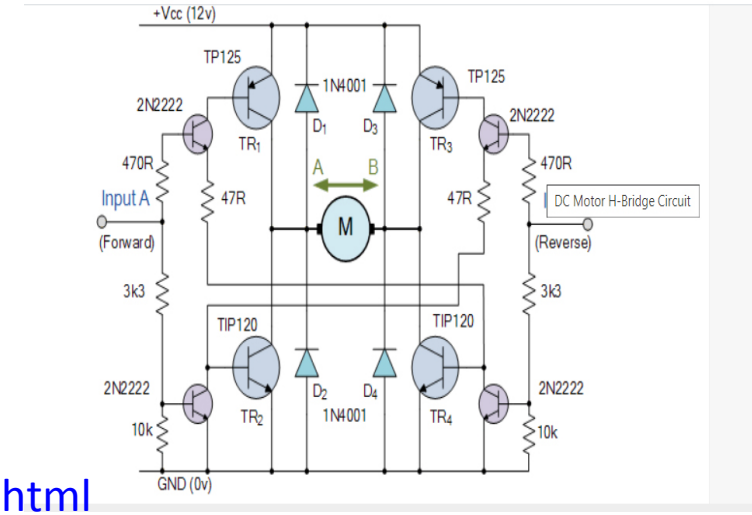
By switching the relays, the motor voltage is reversed and the changes direction of rotation.

https://www.build-electronic-circuits.com/h-bridge/

Reversing the direction of rotation

- To reverse the direction of rotation of a DC motor, a switching matrix called an H-bridge can be used.
- A H-bridge can be configured using simple relays or an electronic device.



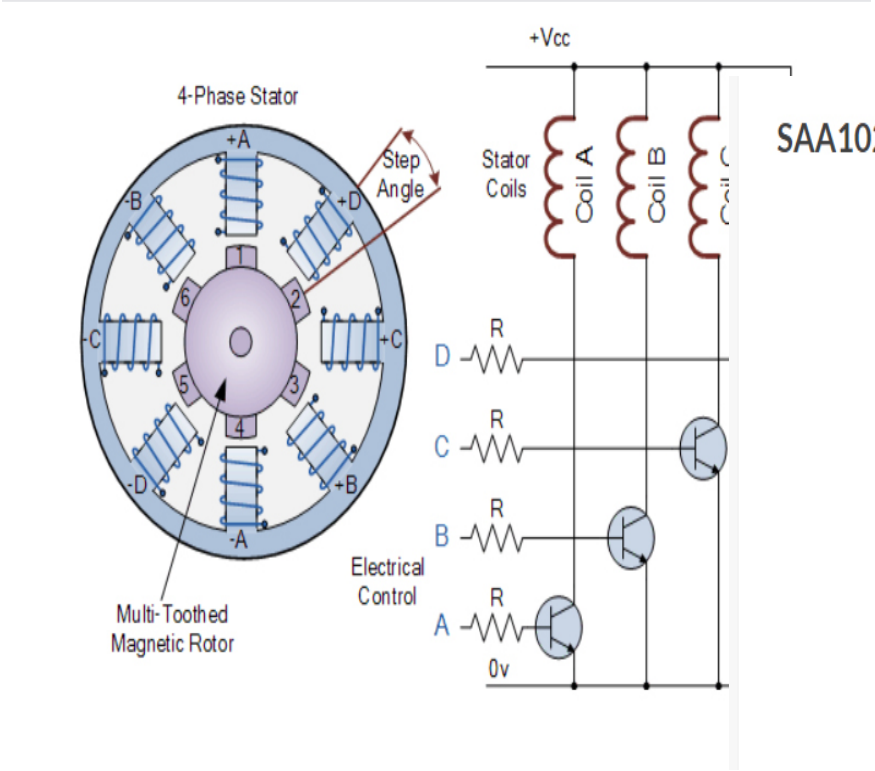


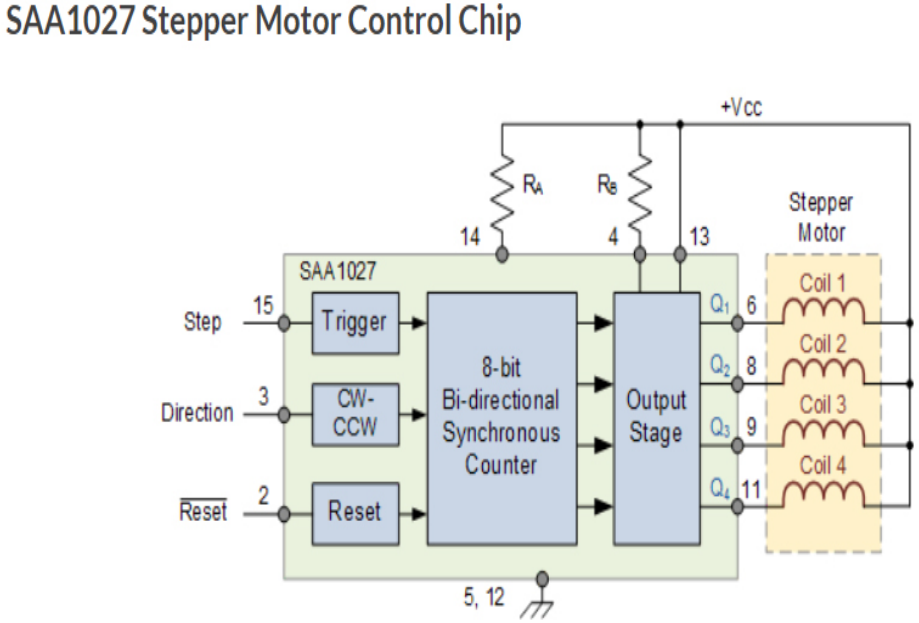
Drawings from
https://www.electronics-tutorials.ws/io/io_7.html

Stepper Motors

- Stepper Motors are DC motor which only move a specific number of degrees at a time.
- Typical Stepper Motors have steps of 1.8 degrees; that is 200 steps.
- Stepper motors have multiple windings to achieve the stepping action. The order in which the multiple windings are energies determines the direction of rotation of the rotor.
- Typically a hardware or software controller is used to facilitate the sequencing of the multiple windings. Therefore, such a controller uses two bits: one for determined direction of rotation and one to send a pulse per step.

Typical Stepper Motor

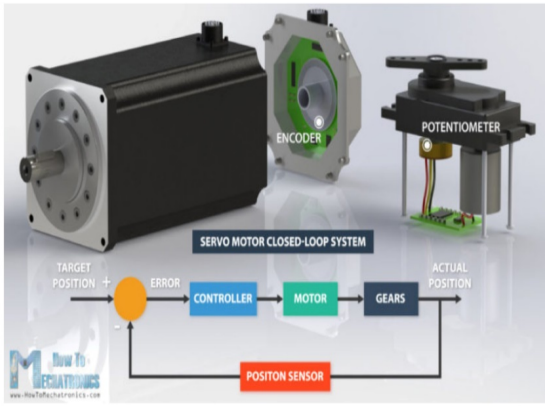


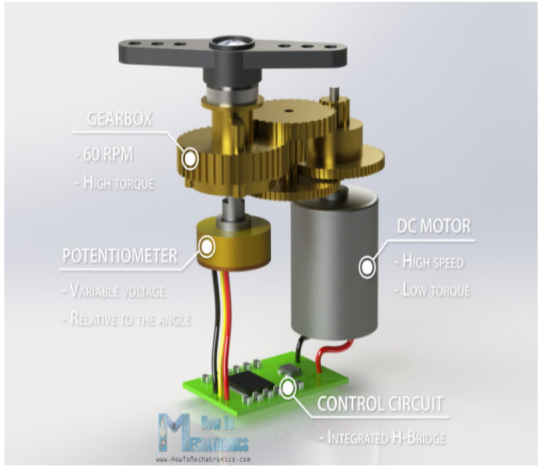


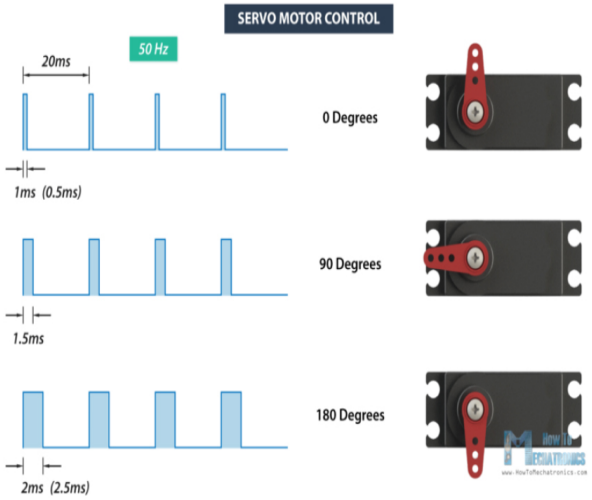
Drawings from
https://www.electronics-tutorials.ws/io/io_7.html

Servo Motor

- A Servo Motor is a DC (or AC) motor which uses a feedback control system to move to specific angles of rotation.
- A Servo Motor requires a PWM signal to move the rotor to a particular angle.



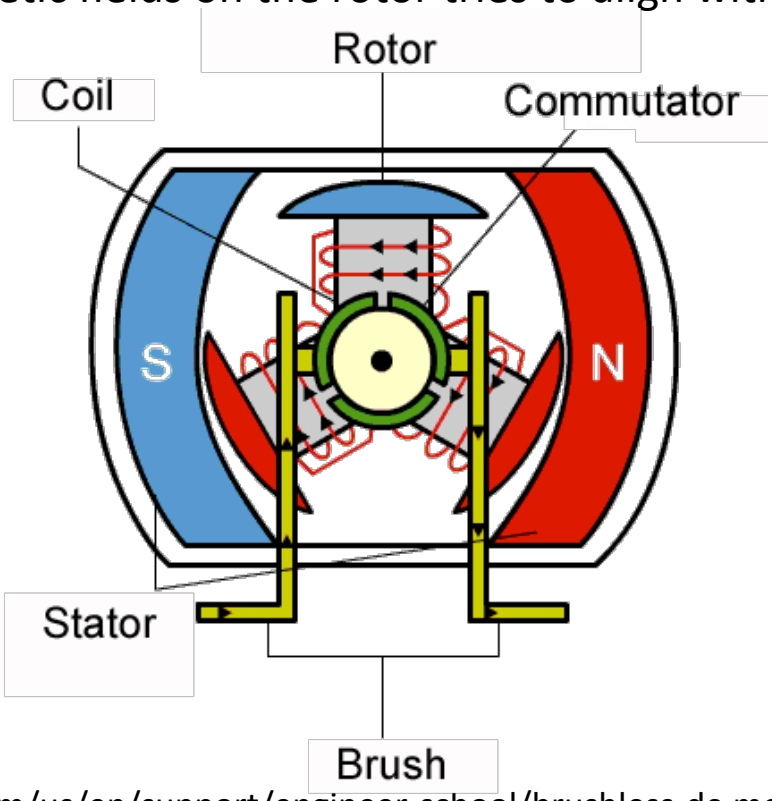




Drawings and photos from
https://howtomechatronics.com/how-it-works/how-servo-motors-work-how-to-control-servos-using-arduino/

Brushless DC Motor

- Standard DC Motor
  - Stator has permanent magnet
  - Rotor has coils wrapped around metallic sections (poles) where current flow magnetizes the poles in sequence through a commutator.
  - The magnetic fields on the rotor tries to align with magnetic field of the stator.

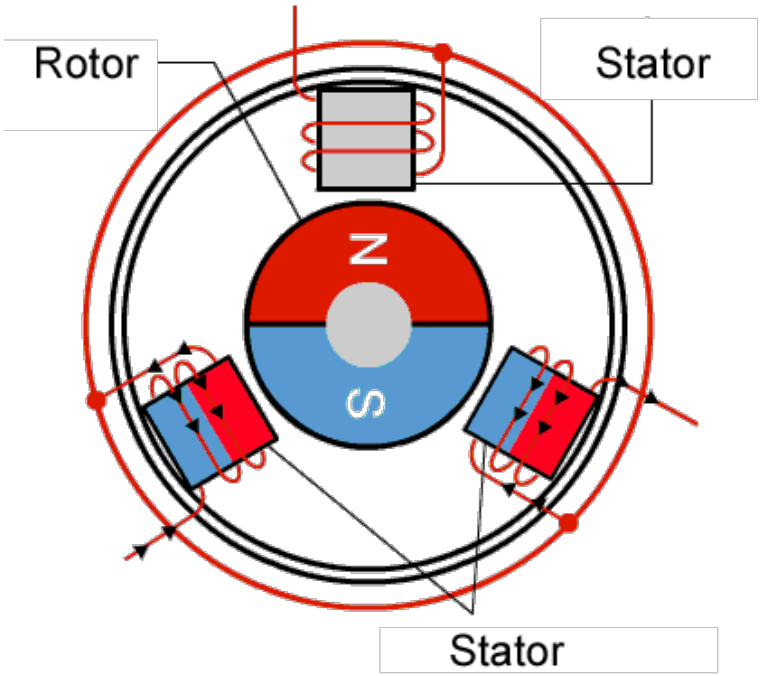


RENESAS

https://www.renesas.com/us/en/support/engineer-school/brushless-dc-motor-01-overview

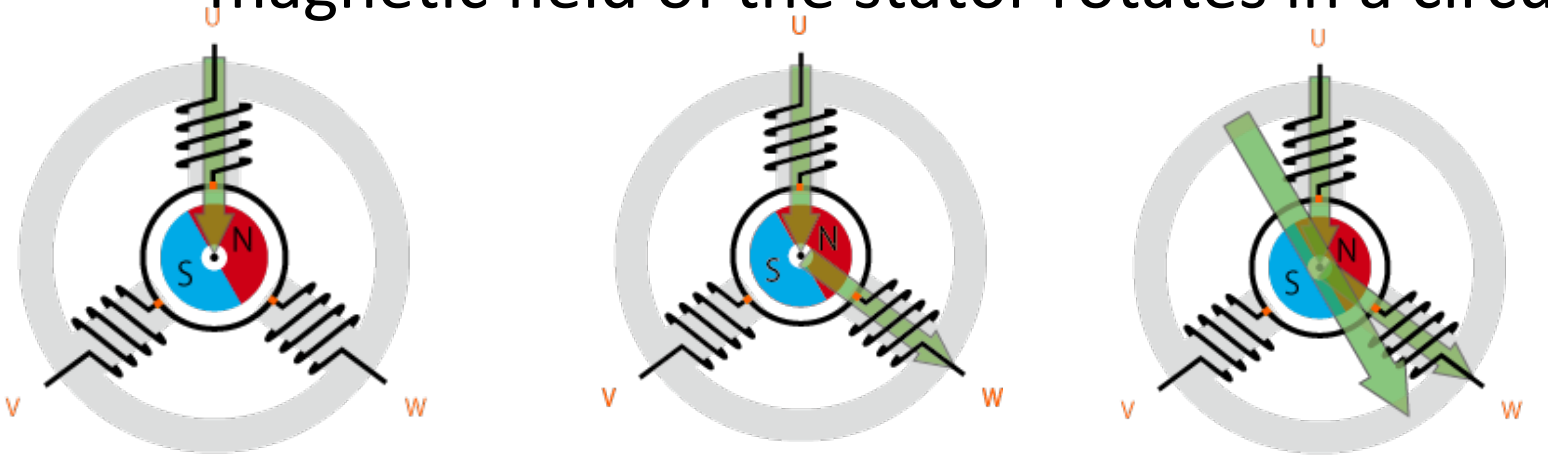
Brushless DC Motor

- Brushless DC Motor
  - Rotor has permanent magnet
  - Stator has coils wrapped around metallic sections (poles) where current flow magnetizes the poles in sequence and no commutator is needed.
  - The magnetic fields on the rotor tries to align with magnetic field of the stator.



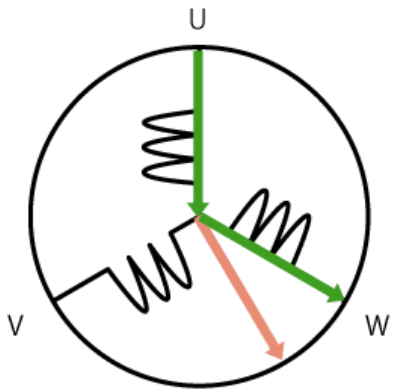
Brushless DC Motor

- Method of control of the rotations.
  1. The poles of the stator are energized in a particular order
  2. As the poles are energized, the resultant magnetic field of the stator rotates in a circular



Brushless DC Motor

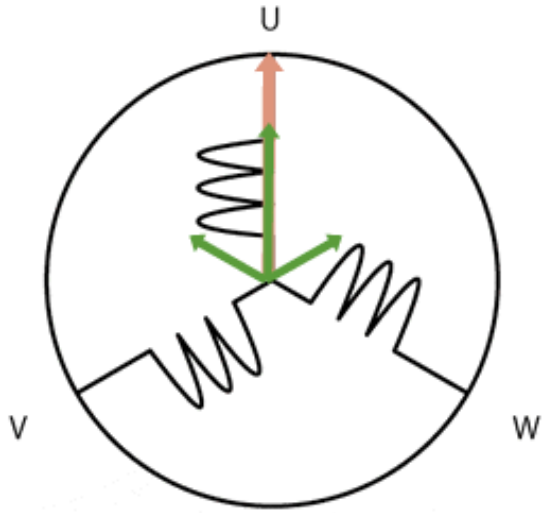
- Here is a video of the sequence to rotate the stator magnetic field.



Energizing Mode	Energized Phase	Resultant Flux
1	U → W	
2	U → V	
3	W → V	
4	W → U	
5	V → U	
6	V → W	

Brushless DC Motor

- Other methods of control of the rotation are:
  - Sinusoid signals at the stator coils provide smoother control.



  - PWM is applied at the coils at various duty cycles to control varying signals (e.g., sinusoidal).
  - Positional sensors (encoders) to aid in assuring the proper direction of rotation