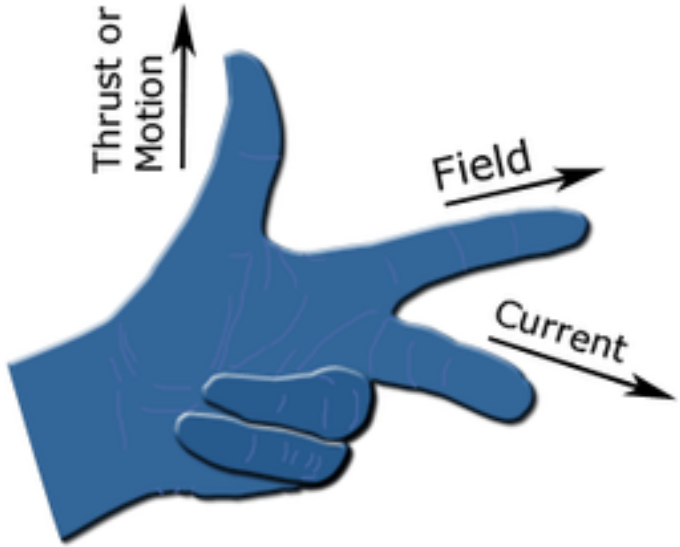
DC Electric Motors

Refresher on the Motor Effect

- When we have a wire with current in a magnetic field the force magnetic field generated by the wire interacts with the existing magnetic force making the wire move
- The magnitude of the force is measured in newtons
- The equation for the magnitude is
- $F = BIL * Sin(\theta)$
- Where:
  - B = Magnetic flux density
  - I = Current through wire
  - L = Length of wire
  - θ = angle between wire and flux
- The units are (NA-1m-1)

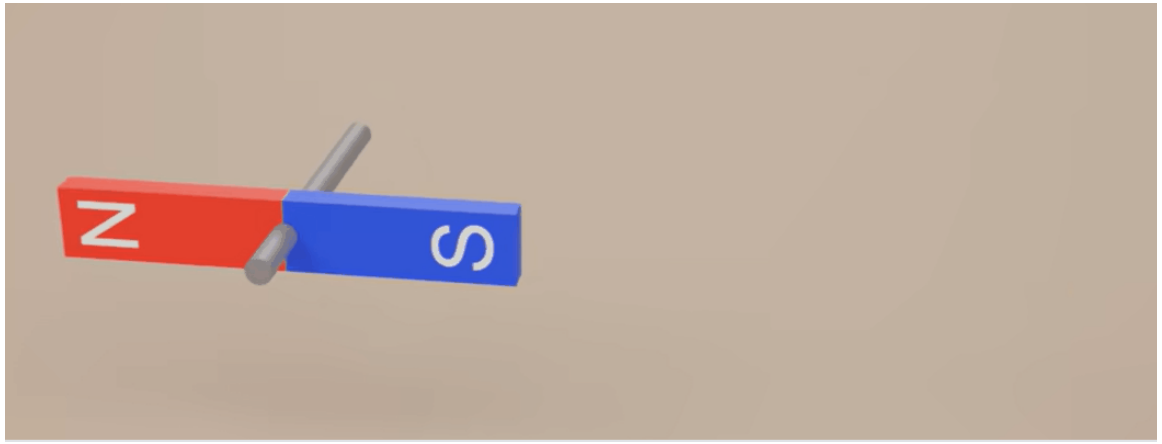


What is a DC motor

- A DC motor converts electrical energy into rotational mechanical energy
- They rely on the Electromagnetic Effects that we looked at
- They are essential for everyday life

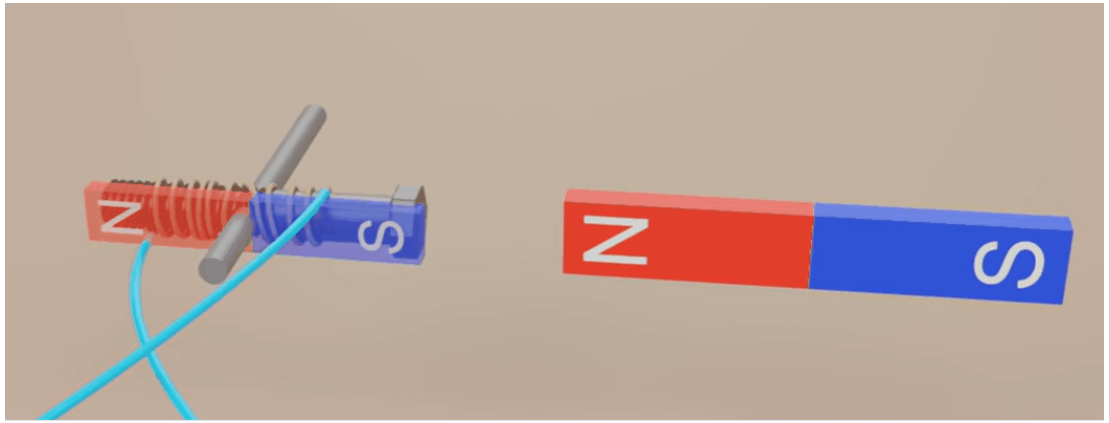
The principle behind DC electric motors

- We know that in magnets like poles repel and opposite poles attract due to magnetic fields
- If we attached a magnet which is allowed to freely rotate onto a shaft, we could use another magnet to manipulate it
- By quickly flipping the magnets we get continuous motion



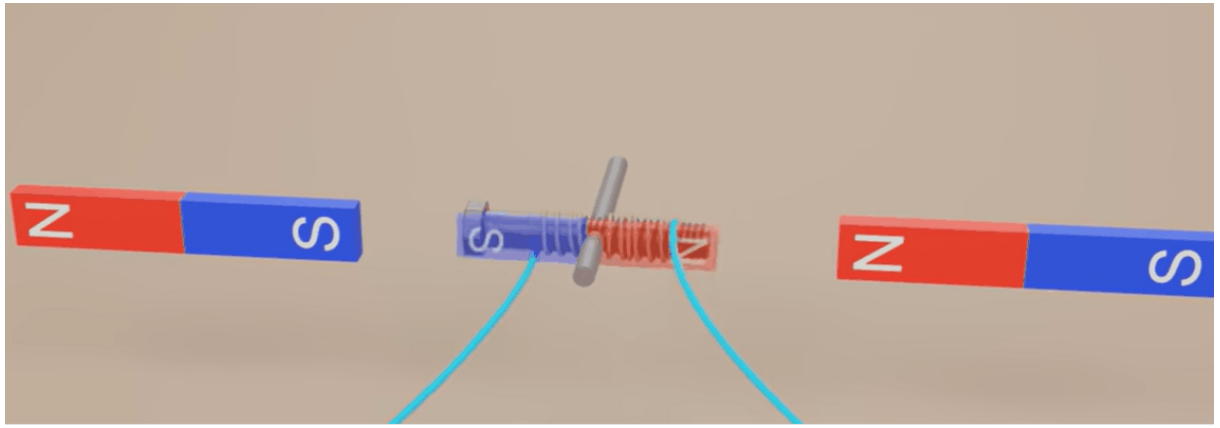
The principle behind DC electric motors

- Manually swapping the polarity of the nonrotating magnet would be impractical
- So instead, we use an electromagnet as the rotating magnet and swap its polarity
- This electromagnet is often just a loop of wire called an armature
- The stationary magnet on the outside becomes a “stator” and the spinning magnet becomes a “rotor”



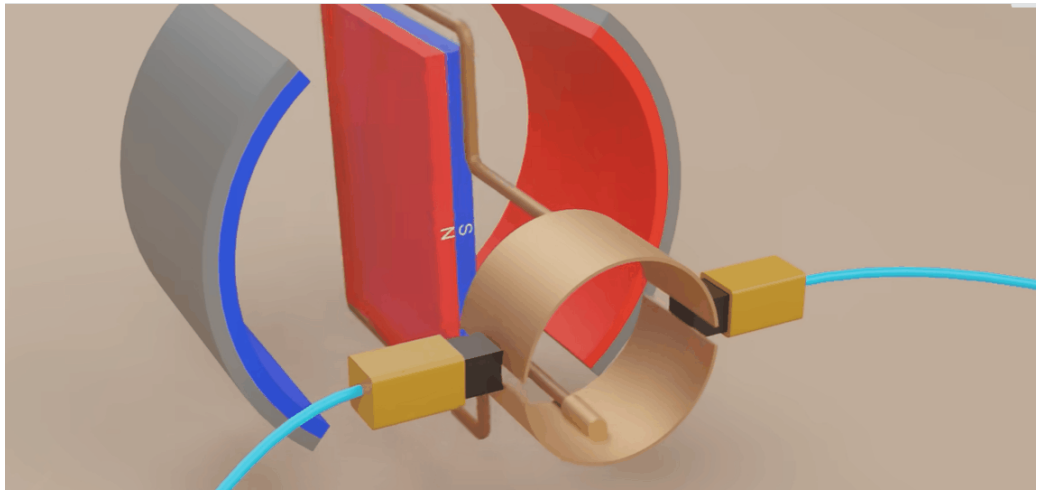
The principle behind DC electric motors

- With one magnet this effect is quite weak
- So we add another magnet (stator) to increase the strength of the magnetic field
- Thes magnets are often replaced with curved wide magnets that have a larger surface area and thus a wider magnetic field
- As magnetic field is directly proportional to Force (from motor effect equation) this increases the torque and thus speed of the motor



The principle behind DC electric motors

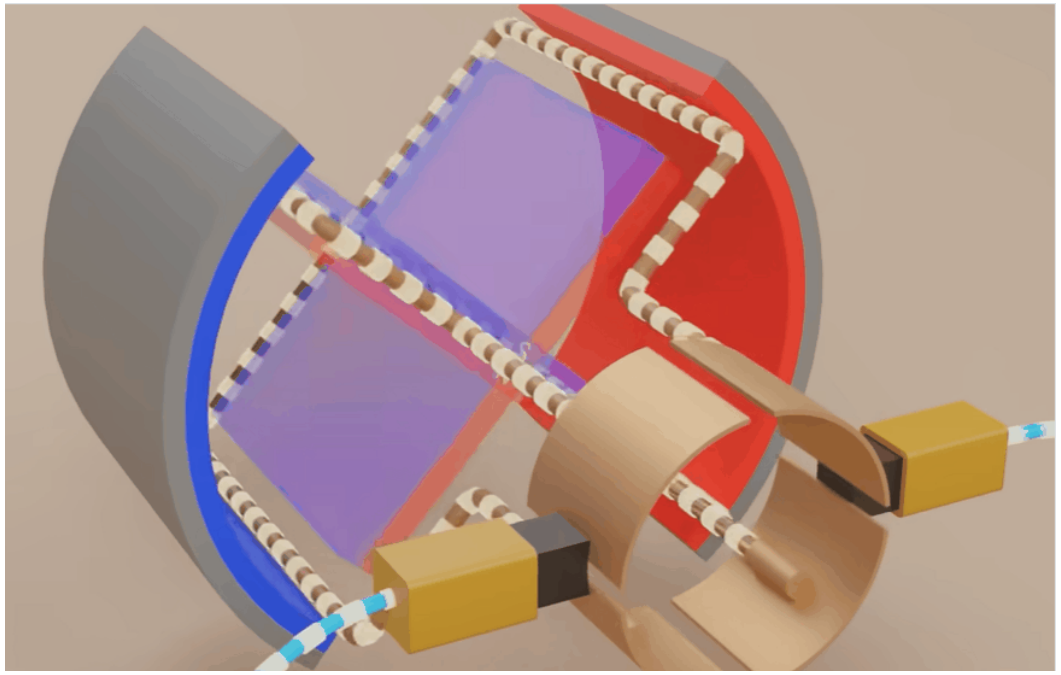
- Manually swapping the wires on the electromagnet is again impractical
- So we use the existing rotational force to swap polarity for us
- To do this we use a commutator and brushes
- As the shaft spins so does the commutator making them connect with the brushes (one + and one -) which then forms a loop



The principle behind DC electric motors

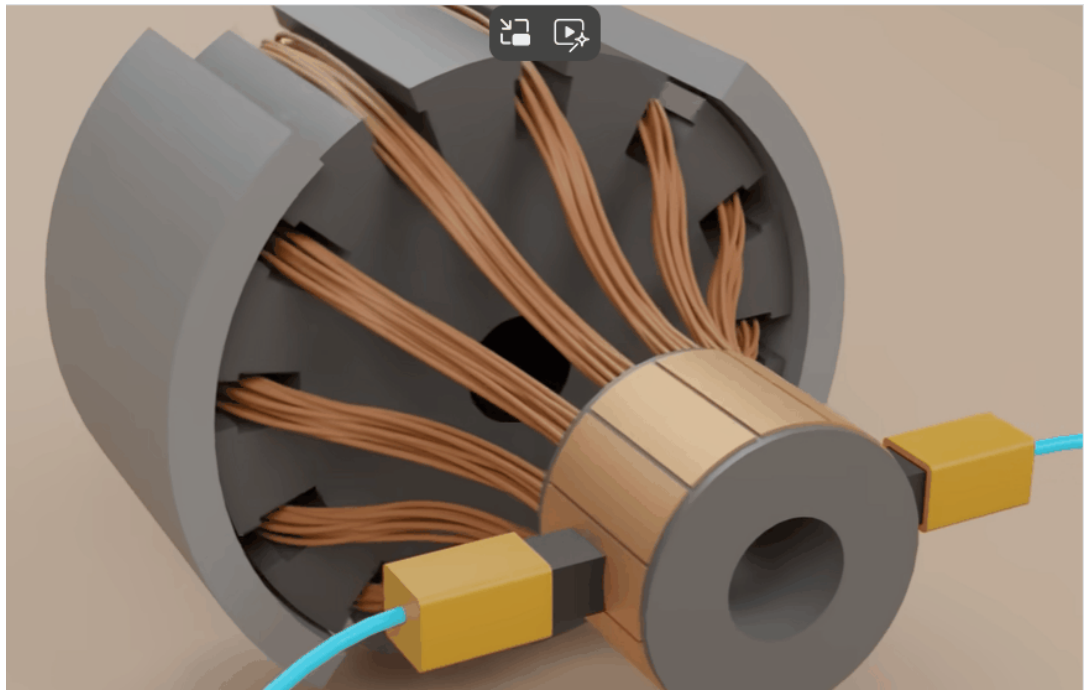
- One armature loop means we end up with irregular speed and the motor can get stuck

- To prevent this, we add more armatures that take turns being the electromagnet making the motor move smoothly



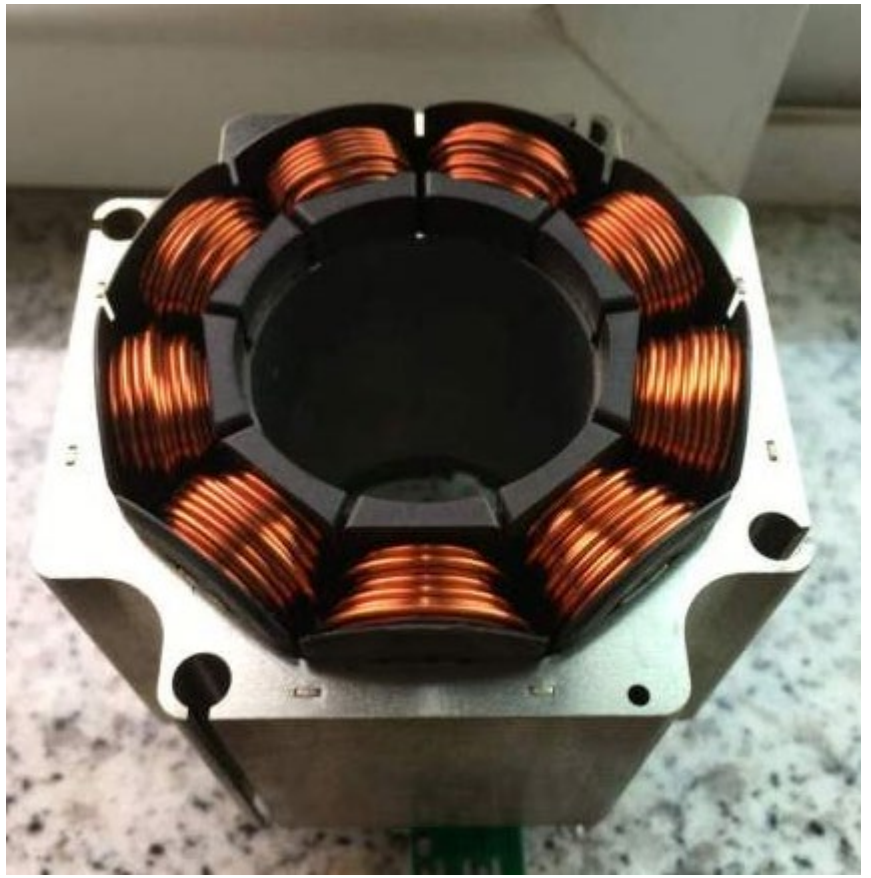
The principle behind DC electric motors

- There are several ways we can increase the torque(speed) of our motor
- The first way to increases torque is to increase the number of armatures
- The second method is adding more windings to each armature as it increases the strength of the electromagnet
- The third method is increasing the current through the armatures as force (torque) is directly proportional to current
- Finally, we can add more powerful magnets as stators which will increase the field strength



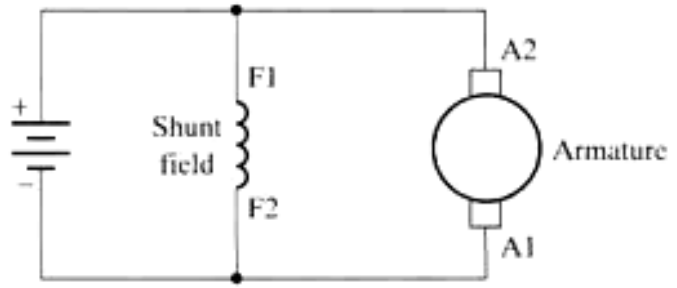
Permanent Magnet vs Electromagnetic Stators

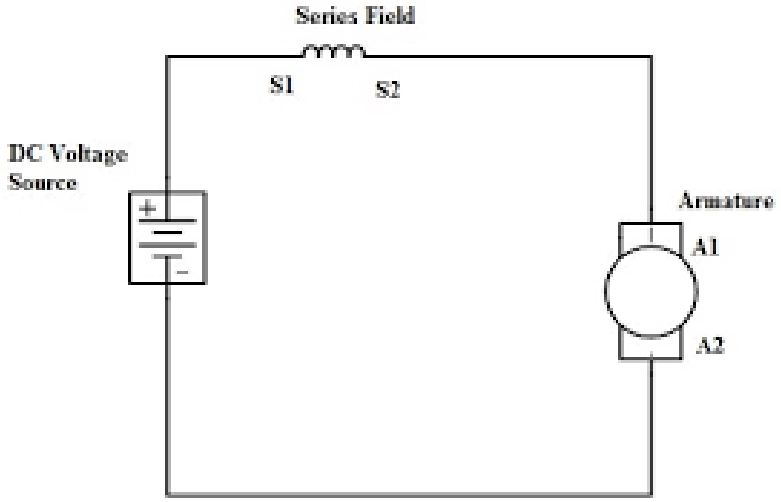
- The motor we have talked about until now has a permanent magnet acting as the stator, we call this “PMDC”
- However, some motors use sets of electromagnets in their stators, these can either be shunt or series wound.
- This allows for speed to be more easily controlled
- This also allows for more torque as an electromagnet will provide a stronger field than a permanent magnet



Shunt vs Series Motor

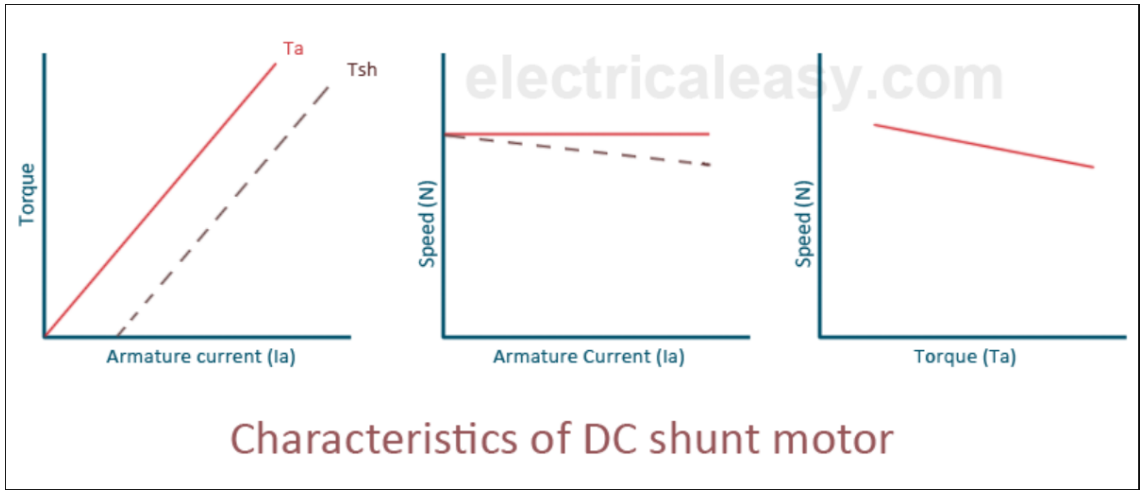
- There are two main ways we can connect an electromagnetic stator in a motor
- Either shunt(parallel) or series





Shunt DC Motor

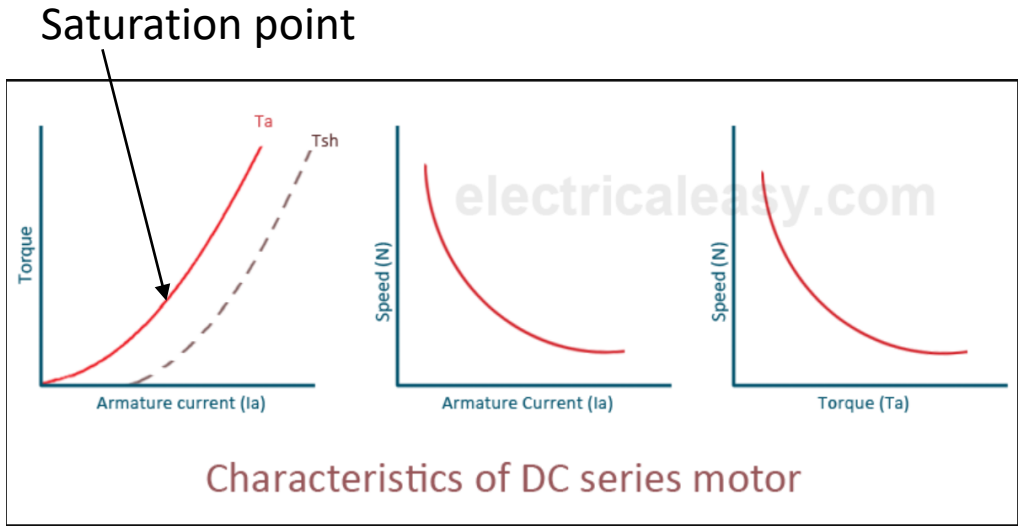
- Connection: The field winding is connected in parallel (shunt) with the armature.
- Current: Field winding gets constant voltage, so field current is steady.
- Speed: Fairly constant speed regardless of load.
- Torque: Lower starting torque.
- Use cases: Ideal for applications needing steady speed like lathes, fans, and conveyors.



Characteristics of DC shunt motor

Series DC Motor

- Connection: The field winding is connected in series with the armature.
- Current: Same current flows through field and armature, so field strength varies with load.
- Speed: Varies a lot with load — can become dangerously high at no load (no field).
- Torque: Very high starting torque.
- Use cases: Perfect for high-torque needs like cranes, elevators, and electric trains.



Practical

- **Work in pairs or 3s, follow the worksheet filling it in as you go**
- BE SAFE!
- Don’t put your hand in anything spinning
- Don’t mess around with the magnets as they are strong, prone to chipping and will pinch fingers
- Follow the instructions
- Don’t short the wires
- Ask me before you turn anything on