9.3.1 Forces on Conductors

Motors use the effect of forces on current-carrying conductors in magnetic fields

Prerequisite Knowledge

- **Charges**
  - **Stationary** charge produces an electric field
  - Stationary charge experiences a force in an external electric field
  - **Moving** charge produces both electric and magnetic field
  - Moving charge experiences a force in both external electric and magnetic fields
  - **Accelerating** moving charge produces electromagnetic radiation
- **Magnetic fields** (shortened to B field at times in KC Notes)
  - **Right hand grip rule**
  - Lines move from **North to South**
  - **Solenoid** produces magnetic field that adds based on loops
    - Direction of B field by RH rule, fingers in direction of current, thumb direction of B field
    - Electromagnet is solenoid with iron core

1.1 Discuss the **effect on the magnitude of the force** on a current-carrying conductor of variations in:

THE **STRENGTH OF THE MAGNETIC FIELD** IN WHICH IT IS LOCATED

- Force **proportional to** magnetic field strength (B) – as strength increases, force increases

THE **MAGNITUDE OF THE CURRENT** IN THE CONDUCTOR

- Force **proportional to** magnitude of current (I) – as current increases, force increases

THE **LENGTH OF THE CONDUCTOR** IN THE EXTERNAL MAGNETIC FIELD

- Force **proportional to** length of wire inside B field (l) – as length increases, force increases

THE **ANGLE BETWEEN THE DIRECTION OF EXTERNAL MAGNETIC FIELD** AND THE **DIRECTION OF LENGTH OF THE CONDUCTOR**

- **Maximum** when conductor is **placed perpendicular** to B field
- **Zero** when **placed parallel** to B field

Overall: $F = BIl\sin\theta$

Where F = force (N), B = magnetic field strength (T [tesla]), I = current (A), l = length of conductor (m), θ = angle

Note θ is **between field lines and conductor** – do not measure based on a perpendicular line

Image of conductor in B field

1.2 Describe **qualitatively and quantitatively** the **force** between long parallel current-carrying conductors: $\boldsymbol{\frac{F}{l} = k\frac{I_1 I_2}{d}}$

- Intensity of magnetic field B is proportional to current and distance $B = k\frac{I_1}{d}$
  - Equating $B = k\frac{I_1}{d}$ and $F = BI_2 l \sin 90$ (as they are parallel) we get the force between two conductors:

$$\frac{F}{l} = k\frac{I_1 I_2}{d}$$

Where F = force (N), l = length of wires (m), k = constant 2×10^{-7}, I_1 and I_2 = currents (A), d = distance between wires (m)

- Force direction is through the **right hand palm rule**
  - Thumb in direction of current, fingers in direction of magnetic field
  - Palm points to the direction of the force

1.3 Define **torque** as the turning movement of a force using: $\boldsymbol{\tau = Fd}$

- **Torque** (τ): turning effect of a force, e.g. turning a nut with a spanner

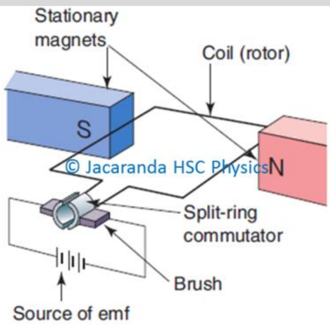
$$\tau = Fd$$

Where τ = torque (Nm), F = perpendicular force (N), d = distance from pivot (m)

1.4 Identify that the **motor effect** is due to the **force** acting on a current-carrying conductor in a magnetic field

- **Motor effect**: when a **current-carrying conductor experiences a force** in a magnetic field
  - Current created by stream of electrons – creating force in a magnetic field
  - Will therefore experience a force in a magnetic field

1.5 Describe the **forces experienced by a current-carrying loop** in a magnetic field and describe the **net result** of the forces



- Current-carrying loop is placed in an **electric motor**
- Current goes **clockwise**
  - Left side: force is **upwards** (RH palm rule)
  - Right side: force is **downwards**
  - Top and bottom side: parallel to magnetic field, thus no force
- Two torques cause the **same rotation** on the coil and spins **clockwise**
- When loop is vertical, torque is 0 (θ = 90°)

1.6 Describe the **main features of a DC electric motor** and the **role** of each feature

- **Magnetic field**: can be provided by a magnet, to create a magnetic field for loop to experience force
  - Can be **a stator** (stationary) or **rotor** (rotating magnetic field)
  - **Radial** magnet: constant rotation speed – angle remains 0° longer, and torque is maximum
- **Armature**: coil of wire inside magnetic field, to maximise torque as it is proportional to number of loops
- **Split-ring commutator**: ring that **changes direction of current**
  - Changes **force directions** and therefore keeps motor spinning one direction
- **Carbon brushes**: conducts current in and out of the coil, as the commutator rotates

LOL GAVE UP LAST BIT I don't know where 1.7 went. Don't ask