Topic 22 Magnetic fields

Summary

- A magnetic field is a region of space where a magnet will experience forces.
- A magnetic field can be represented by magnetic field lines. Magnetic field lines never touch or cross.
- The separation of magnetic field lines indicates the strength of the magnetic field.
- The direction of the magnetic field is given by the direction in which a free magnetic north pole would move, if placed in the field.
- There is a force on a current-carrying conductor whenever it is at an angle to a magnetic field.
- The direction of the force is given by Fleming's left-hand rule – place the first two fingers and thumb of the left hand at right angles to each other, first finger in the direction of the magnetic field, second finger in the direction of the current, then the thumb gives the direction of the force.
- The magnitude of the force F on a conductor of length L carrying a current I at an angle θ to a magnetic field of flux density B is given by the expression $F = BIL \sin \theta$.
- Magnetic flux density (field strength) is measured in tesla (T). $1\text{T} = 1\text{Wb m}^{-2}$.
- The force F on a particle with charge q moving at speed v at an angle θ to a magnetic field of flux density B is given by the expression: $F = Bqv \sin \theta$.
- The direction of the force is given by Fleming's left-hand rule – place the first two fingers and thumb of the left hand at right angles to each other, first finger in the direction of the magnetic field, second finger in the direction of motion of positive charge, then the thumb gives the direction of the force.
- The path of a charged particle, moving at constant speed in a plane at right angles to a uniform magnetic field, is circular.
- The Hall voltage V_H is given by the expression $V_H = BI/ntq$.
- An electric current gives rise to a magnetic field, the strength and direction of which depends on the size of the current and the shape of the current-carrying conductor.
- The direction of the field due to a straight wire is given by the right-hand rule.
- The direction of the field in a solenoid is given by the right-hand grip rule.
- The field of a solenoid may be increased in strength by a ferrous core; this is the principle of an electromagnet.
- The force between parallel current-carrying conductors provides a means by which the ampere may be defined in terms of SI units.
- Nuclear magnetic resonance imaging (NMRI) – shortened to magnetic resonance imaging (MRI) – monitors the concentration of hydrogen nuclei in the body.
- Hydrogen nuclei have 'spin' which causes them to precess in an applied magnetic field.
- The frequency of precession (the Larmor frequency) depends on the magnetic flux density applied to the nuclei.
- A radio-frequency pulse at the Larmor frequency causes the nuclei to resonate.
- On de-excitation, the nuclei give off radio-frequency waves that can be detected and analysed.

Definitions and formulae

- Magnetic force $F = BIL \sin \theta$, B is the magnetic flux density
- Unit of B: T (tesla)
- Magnetic force on a charge $F = Bqv \sin \theta$
- Fleming's left-hand rule: if the first two fingers and thumb are held at right angles to one another with the First finger in the direction of the Field and the seCond finger the Current, then the thuMb gives the direction of the force or Motion.
- For a long straight conductor carrying unit current at right angles to a uniform magnetic field, the magnetic flux density is numerically equal to the force per unit length of the conductor.
- One tesla is the unit of magnetic flux density which, acting normally to a long straight wire carrying a current of one ampere, causes a force of one newton per metre on the conductor.
- Hall voltage $V_H = BI/ntq$
- Velocity selector: $v = E/B$