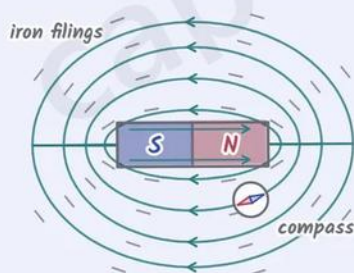


a bar magnet is a current loop that never lost its current

The bar magnet and its field lines

- outside the magnet the lines run N to S, inside they run S to N
- so every line is a closed loop, none starts or ends
- the tangent to a line is the direction of B there
- lines crowd together where the field is strong: near the poles
- two lines never cross
- iron filings and a compass both trace the lines

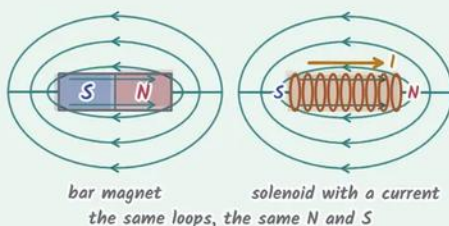


outside the magnet the lines run N to S

lines leave N, run round outside to S and close through the magnet; filings lie along them and the compass needle follows

A bar magnet is a solenoid *

- its field matches a solenoid's, loop for loop
- magnetic moment $\mathbf{m}$: points S to N, $m = nIA$ for n turns
- a loop is a dipole: its N face is where the current runs anticlockwise
- the atoms' own circulating charges are the tiny loops inside the bar

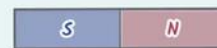


bar magnet solenoid with a current
the same loops, the same N and S

a bar magnet and a solenoid with a current draw the same field loops, with N at the same end

Cut it: no lone pole

- cut a magnet in two and you get two magnets, never two lone poles
- an isolated N or S pole has never been found
- every piece keeps its own N and S, in the same order
- poles are a picture, the real source is the moving charge



a bar



two magnets



four magnets

every piece has its own N and S

a bar, cut in two, cut in four: every piece shows its own S and N

The far field of a bar magnet

on the axis (r far greater than the length)

$$B_{\text{axis}} = \frac{\mu_0}{4\pi} \frac{2m}{r^3}$$

on the equator (same r)

$$B_{\text{eq}} = \frac{\mu_0}{4\pi} \frac{m}{r^3}$$

the two compared

$$B_{\text{axis}} = 2B_{\text{eq}}$$

the equatorial field points against $\mathbf{m}$, the axial field along it: the electric dipole's pattern again, with $\mu_0/4\pi$ in place of $1/4\pi\epsilon_0$