

a bar magnet in a field, then why iron, nickel and cobalt behave so differently from everything else

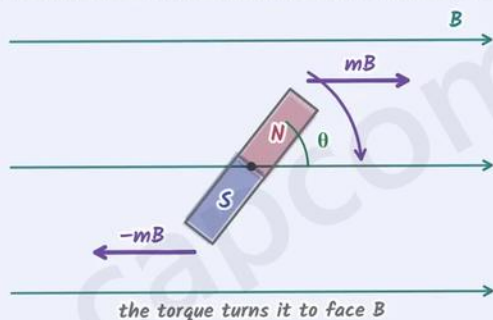
Torque on a magnetic dipole in a uniform field

torque, theta between m and B

$$\tau = m \times B$$

magnitude

$$\tau = mB \sin \theta$$



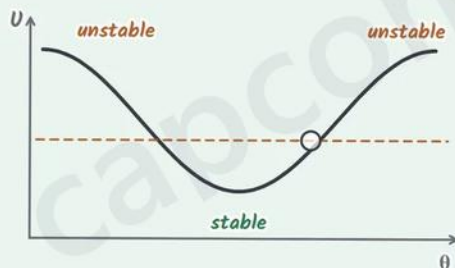
the torque turns it to face B

a force along B on the N end and against B on the S end make a couple that turns the magnet toward B
the same equation as a current loop's torque: a short bar magnet IS a magnetic dipole of moment m

Potential energy of a magnetic dipole

general angle theta

$$U_m = -mB \cos \theta$$



aligned is lowest, opposed is highest

U against θ is a well: stable at the bottom, unstable at both tops; the dashed level is the swing's energy
a freely suspended bar magnet settles along the field, where potential energy is least

Special angles of a magnetic dipole

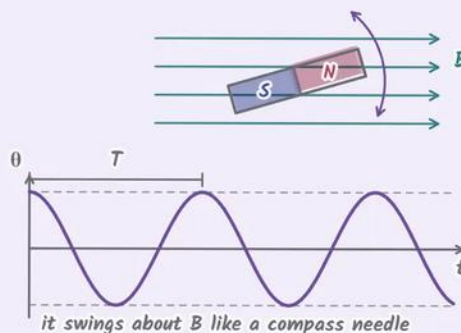
$$U_m = -mB \cos \theta$$

$\theta = 0^\circ$, m parallel to B	→ minimum, most stable orientation	$U_m = -mB$
$\theta = 90^\circ$, m perpendicular to B	→ zero potential energy	$U_m = 0$
$\theta = 180^\circ$, m antiparallel to B	→ maximum, most unstable orientation	$U_m = +mB$

Small oscillations of a suspended magnet

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- small-angle restoring torque $\tau = -mB \sin \theta \approx -mB \theta$ matches angular SHM
- this gives $I \frac{d^2 \theta}{dt^2} = -mB \theta$, with $\omega^2 = \frac{mB}{I}$
- a vibration magnetometer uses this swing to compare moments or find Earth's horizontal field



the magnet swings about B and its angle against time is a wave of steady height with period T

Time period of oscillation

angular frequency

$$\omega = \sqrt{\frac{mB}{I}}$$

time period

$$T = 2\pi \sqrt{\frac{I}{mB}}$$

I is the magnet's own moment of inertia about the suspension axis, not a current: bigger I or weaker B means slower swings