Chapter 27 P1 V1 ....../....../.......

Manisa

Magnesia ad Sypilum

priene, Ephesus and Tralles trade route

Aydın

"don't forget the way home"

Magnets have two poles,

the one that points towards north → north pole N

the one that points toward south → south pole S

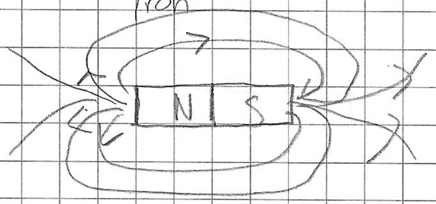
Similar poles repulse, opposite poles attract

if you split a magnet in two, you still have N and S poles : No magnetic monopole has ever been observed.

Only iron, and a few other materials such as cobalt, nickel, gadolinium, and some of their oxides show strong magnetic fields

Ferromagnetic

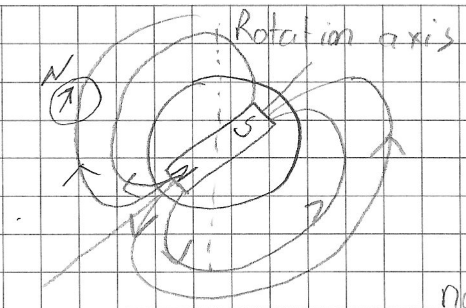
iron



- Magnetic field is tangent to the field line
- Intensity is proportional to the # field lines

Magnetic field always forms loops (no monopole)

direction : North pole side of the compass



earth magnetic field

north magnetic pole → South pole of earth's magnetic field

north magnetic pole ≠ geographic north pole

geomagnetic

rotation axis

Since the magnetic field lines are not parallel to the surface → "angle of dip" is the angle btw field line and horizontal

the difference btw geographical north and geomagnetic north has to be taken into account → magnetic declination (magnetic maps)

Uniform magnetic field

Simplest form of magnetic field

does not change from one point to another

not easy to produce

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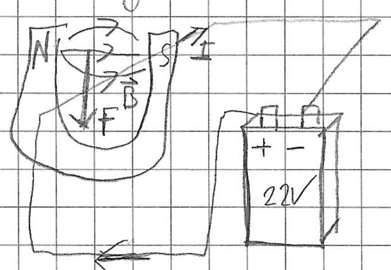
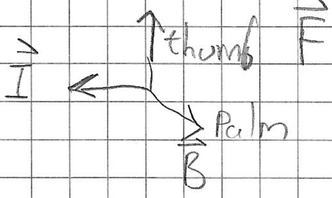
Electric currents and magnetic fields

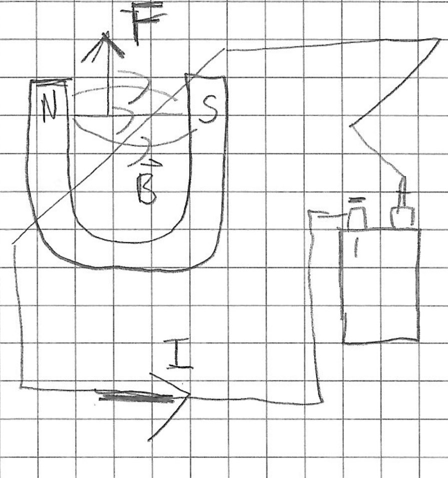
1820 Hans Christian Oersted

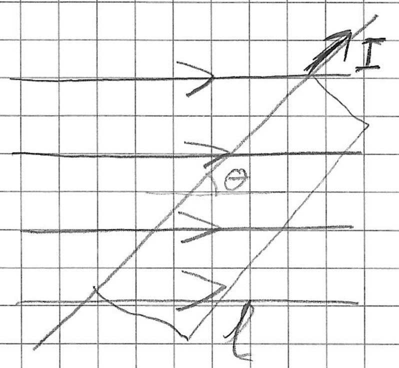
an electric current produces a magnetic field

right-hand rule









$$F = I \ell B \sin\theta$$

$$\vec F = I \vec \ell \times \vec B$$

where $\vec \ell$ is a vector along the current direction with magnitude equal to the length of wire exposed to the magnetic field

Generalisation

$$d\vec F = I d\vec \ell \times \vec B$$

(This can serve as a practical definition of $\vec B$)

The SI unit for magnetic field B is Tesla

earth → 0.5×10^{-4} T

refrigerator → 0.01 T

MR → 2T (can hold paper)

ex Magnetic force on a current-carrying wire

30A current $l = 12$cm exposed to $\vec{B}$ at $\theta = 60°$
0.90T

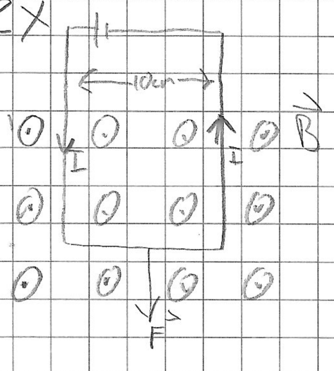
$F = IlB\sin\theta = (30A)(0.12m)(0.90T)(0.866) = 2.8N$

Diagram note

⊙ tip of an arrow towards you out from paper

⊗ back of an arrow moving away

ex



$I = 0.245A$ $\vec{F} = 3.48 \times 10^{-2}N$
what is $\vec{B}$

force from left and right cancel out

only lower part contributes

$$B = \frac{F}{Il\sin 90} = \frac{3.48 \times 10^{-2}N}{(0.245A)(0.1m)} = 1.42T$$

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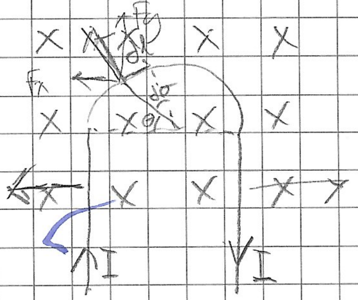


the left and right wires carry $I\ell B_0$ to opposite directions

length of infinitsimal wire of the curve

$$|d\ell| = R\,d\phi$$

the angle of $d\vec{\ell}$ wire with $\vec{B} = 90°$

$$d\vec{F} = I\,d\vec{\ell} \times \vec{B} \longrightarrow dF = I\,RB\,d\phi$$

$$F_x = \int_0^{\pi} dF\cos\phi \rightarrow 0 \quad (\text{symmetric integral}$$

$$F_y = \int_0^{\pi} dF\sin\phi = IB_0R\int_0^{\pi}\sin\phi = -IB_0R\cos\phi\Big|_0^{\pi}$$

$$= 2IB_0R$$

Up towards $+y$

Force on an electric charge moving in magnetic field

$$I = Nq/t$$

ℓ: length q travels in $\vec{B}$

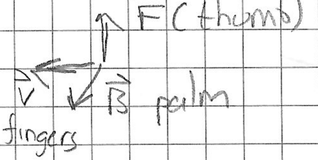
$$\vec{\ell} = \vec{v}t$$

$$\vec{F} = I\vec{\ell} \times B = \frac{Nq}{t}(\vec{v}\,t) \times \vec{B} = Nq\,\vec{v} \times \vec{B}$$

$$\boxed{\vec{F} = q\vec{v} \times \vec{B}}$$

$F = qvB\sin\theta \rightarrow \theta = 90$ max

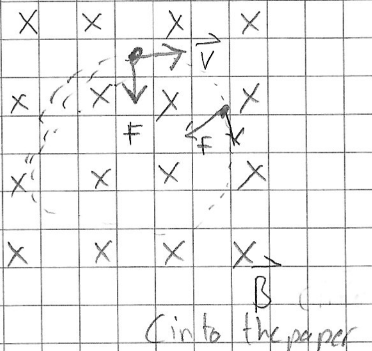
Right hand rule



question will +q at rest move near a magnet

No

Path of a charged particle in Uniform $\vec{B}$ field



force is always perpendicular to $\vec{v}$ so $|v|$ does not change

since $|v|$ is always the same but the charge is being deflected

→ circular path, centripetal acceleration

$a = v^2/r$

$$\underset{qvB}{\overset{\uparrow}{\sum F}} = \underset{m\frac{v^2}{r}}{\overset{\uparrow}{ma}}$$

$$\boxed{r = \frac{mv}{qB}}$$

the time it takes for the charge to turn:

$$T = \frac{2\pi r}{v} = \frac{2\pi m}{qB}$$

frequency $f = \frac{1}{T} = \frac{qB}{2\pi m}$ → cyclotron frequency

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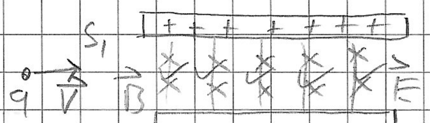
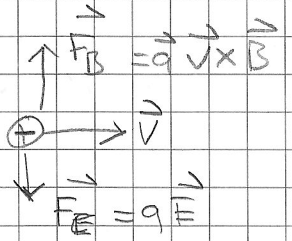
The Lorentz equation

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

It is a basic equation in physics

Velocity selector

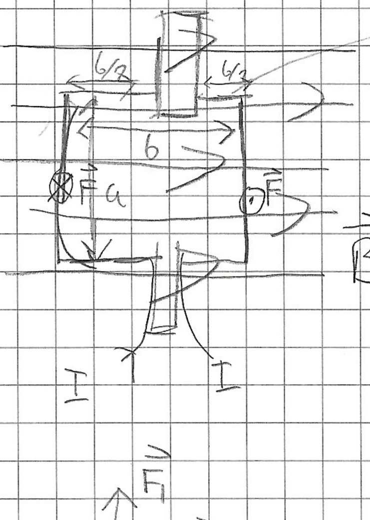




if $\vec{F}_B = \vec{F}_E$ particle crosses the filter

$qvB = qE \Rightarrow v = \frac{E}{B}$ (does not depend on q)

Torque on a current loop



$|\vec{\tau}| = IaB\frac{b}{2} + IaB\frac{b}{2} = IaBb$

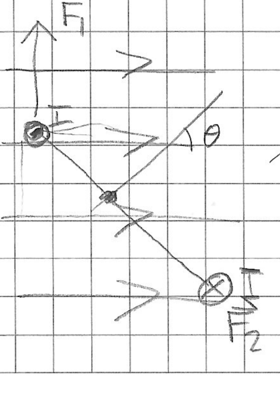
$= I\underset{\uparrow \text{ area}}{A}B$

N loops →

$|\vec{\tau}| = NIAB$

length of the lever arm is $\frac{b}{2}\sin\theta$

$\tau = NIAB\sin\theta$



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magnetic dipole moment is defined as

$$\vec{\mu} = N I \vec{A}$$

↳ unit norm of the plane

So, torque is

$$\vec{\tau} = N I \vec{A} \times \vec{B}$$

$$\boxed{\vec{\tau} = \vec{\mu} \times \vec{B}}$$

$$U = \int \tau \, d\theta = \int N I A B \sin\theta \, d\theta = -\mu B \cos\theta + C$$

$$U = 0 \text{ at } \theta = \pi/2 \rightarrow C = 0 \text{ at } \theta = \pi/2$$

$$U = -\mu B \cos\theta = -\vec{\mu} \cdot \vec{B}$$

Torque on a circular coil

diameter 20.0 cm 10 loops 3.0 A

2.00 T magnetic field

max and min torque?

$$A = \pi r^2 = \pi (0.1)^2 m^2 = 3.14 \times 10^{-2} m^2$$

max torque $\theta = 90$ (face parallel to the $\vec{B}$)

$$\tau = N I A B \sin\theta = (10)(3.00A)(3.14 \times 10^{-2} m^2) 2T$$

$$= 1.88 \text{ N.m}$$

min torque $\theta = 0$ $\tau = 0$

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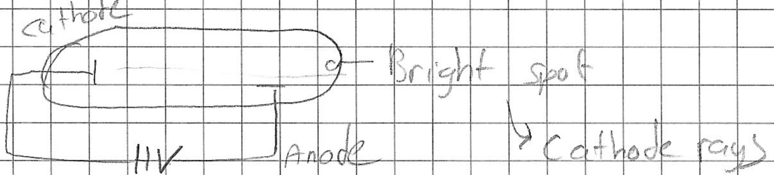
Discovery of the electron

1890s (e⁻ age?)



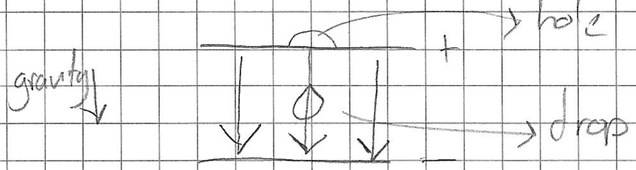
$F = eF$

$F = evB$

$evB = m\frac{v^2}{r} \rightarrow \frac{e}{m} = \frac{v}{Br}$

$F = eE = evB$ $v = E/B$ $\frac{e}{m} = \frac{E}{B^2 r}$

Millikan oil-drop experiment



$qE = mg$

$q = \frac{mg}{E}$

terminal velocity → mass of the droplet

long experiments → unit of charg $1.6 \times 10^{-19} C$

$\frac{e}{m} = \frac{1.6 \times 10^{-19} C}{m} = 1.76 \times 10^{11} C/kg$

$m_e = 9.11 \times 10^{-31} kg$ (thus it is a part of atom)

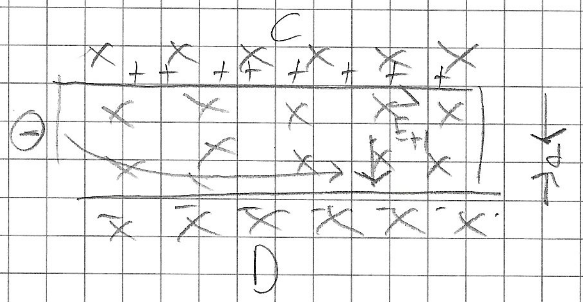
1/1000th of H mass

The Hall effect

Nobels

1985 → quantized hall effect
1998 → fractional charged excitations
2016 → topological phases
2010 → graphene

Edwin H Hall observed an unexpected electrical phenomenon in 1874



when a current carrying conductor is in a magnetic field the electrons move towards one of the faces

$$\vec{F}_B = e\vec{V}_d \times \vec{B}$$

This creates an electric potential difference btw two sides until

$$eE_h = ev_d B$$

Hall emf is

$$\mathcal{E}_H = E_h d = V_d B d$$ where d=width

Hall probe → measures strength of magnetic fields