Charged particles

Observing the force

Direction
of
conventional ***current***

Direction
of
flow of ***positive charge***

Direction
of
flow of ***electrons***

Observing the force

Electron beam tube

to demonstrate the magnetic force on a moving charge

Electron gun

a beam of electrons

Magnets

magnetic field

page 387, figure 26.4

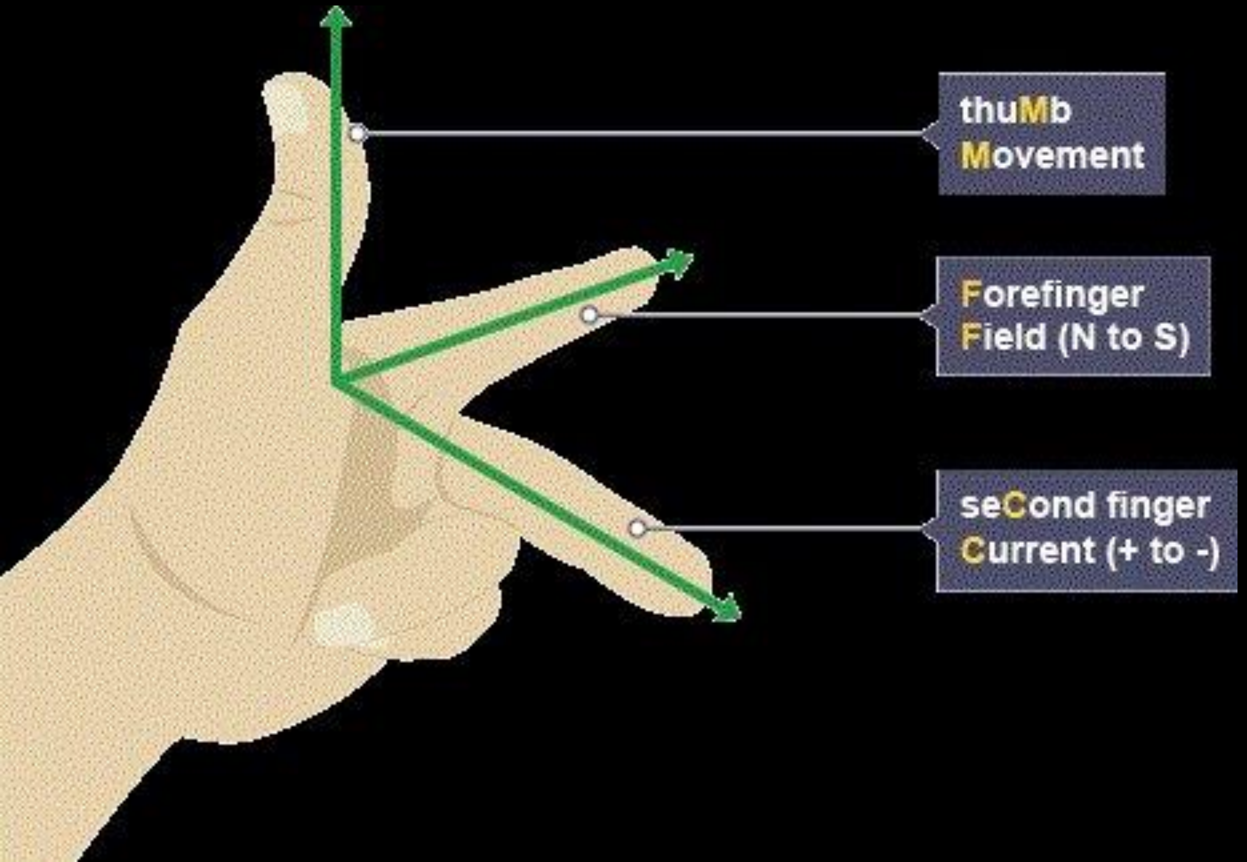
Observing the force

You can *observe* → the effect of

- changing the *magnitude* of the field
- changing the *direction* of the field
- *reversing* the field

Observing the force

Fleming's left-hand rule



thumb – force

forefinger – field

second finger – current

Observing the force

Deflection of
electron beams in magnetic field

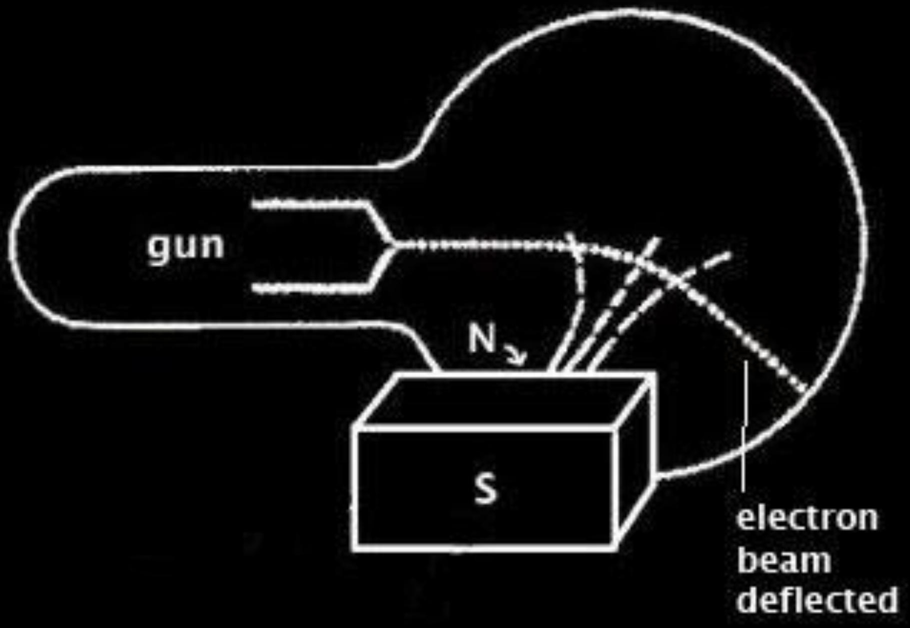
Electrons – from right to left

Magnetic field – into the plane of paper

Force – upwards

page 388, figure 26.3

Observing the force



Force due to the magnetic field is always at right angles to the velocity of the electrons

when direction of the beam changes,
the direction of the force changes

page 388, figure 26.3

Observing the force

Electron beam tube

<u>Electron gun</u>

a beam of electrons

<u>Magnets</u>

magnetic field

<u>Cathode</u>

electrons

<u>Anode</u>

attracts electrons

<u>Plates</u>

changes direction

page 387, figure 26.4

The magnetic force on a moving charge

Force on a charge depends on

- the magnetic field flux density B
- the charge Q on the particle
- the speed *v* of the particle

$$F = BQv$$

'Bev' force

$$F = Bev$$

The magnetic force on a moving charge

Fleming's
left-hand rule

The force is
always at 90° to
the velocity

So arc is formed

The magnetic force on a moving charge

$$F = BIl \quad \Leftrightarrow \quad F = BQv$$

$$I = \frac{Q}{t}$$

The magnetic force on a moving charge

So fucking important reminder:

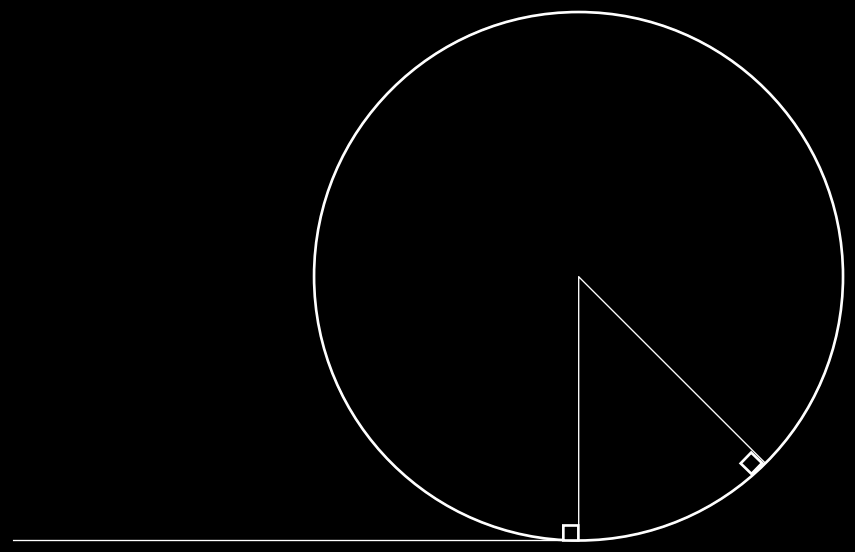
"The net force *F* is always at right-angles to the particle's velocity *v*"

Orbiting charges

when a charged particle is moving at right angles to a uniform magnetic field

charged particle forms a circular path

because



The magnetic force F is always perpendicular to its velocity v

page 390, figure 26.8

Orbiting charges

centripetal force = $\frac{mv^2}{r}$

centripetal force = Bev

$$r = \frac{mv}{Be}$$

$P = Ber$

Orbiting charges

From $$r = \frac{mv}{Be}:$$

- Fast particles form bigger circles $r \sim v$
- Heavier particles form bigger circles $r \sim m$
- Weaker field forms bigger circles $r \sim \frac{1}{B}$

The charge-to-mass ratio of an electron

To find the mass
of an electron

First find the
charge-to-mass ratio $\frac{e}{m}$

The charge-to-mass ratio of an electron

From $r = \frac{mv}{Be}$:

$$\frac{e}{m_e} = \frac{v}{Br}$$

To find v :

cathode-anode voltage V_{ca}

The charge-to-mass ratio of an electron

V_{ca} causes each electron to accelerate

If each electron has charge $-e$

Work done on each electron is $e * V_{ca}$

This is its KE ($= \frac{1}{2} m_e v^2$)

The charge-to-mass ratio of an electron

$$eV_{ca} = \frac{1}{2} m_e v^2$$

$$r = \frac{m_e v}{Be}$$

$$\frac{e}{m_e} = \frac{2V_{ca}}{r^2 B^2}$$

Now, we need [V_{ca} | r | B]

Electric and Magnetic fields

Deflection tube

a beam passes through electric and magnetic fields

to keep the beam horizontal, you can balance the forces the magnetic and electric fields provide

page 391, figure 26.9

Electric and Magnetic fields

To keep the electron beam to be straight:

forces of the two fields must have

- same magnitude
- opposite directions

Electric and Magnetic fields

electric force ⬆ = *magnetic force* ⬇

$$eE = Bev$$

$$v = \frac{E}{B} \longrightarrow E = \frac{V}{d} \longrightarrow v = \frac{V}{Bd}$$

Velocity selection

Velocity selector

a device that uses a process of balancing the effects of *electric* and *magnetic* fields to produce a beam of desired *speed*

page 392, figure 26.11

Velocity selection

Only particles with correct combination of
[*charge* | *mass* | *velocity*] will emerge through slit

Discovering the electron

J.J. Thomson

the English physicist who discovered the electron using the vacuum tube

J.J. Thomson's summary of observation:

Thomson's conclusions

Electrons have negative charge

Electrons remain as a tight beam after deflection

The beam remains straight when there's balance between forces

J.J. Thomson’s summary of observation:

Particles were deflected towards a positive plate

So particles were negatively charged

From deflection of the beam by magnetic field

J.J. Thomson's summary of observation:

When deflected, the beam
remained as a tight, single beam

instead of being broad beam

Particles all have same [mass | charge | speed]

J.J. Thomson's summary of observation:

The beam remained straight due to the balance of the forces of electric and magnetic field

From there, he could calculate $\frac{e}{m_e}$

Measuring *e*

Robert Millikan

the American physicist
who measured *e*

Measuring *e*

Millikan's procedure

He produced oil droplets

using atomizer spray

He determined velocity (and weight)

when the electric field was switched off

He determined that the droplet's weight was balanced by the electric force

Switched the field on and adjusted until the droplet remained stationary

The droplet that absorbed an electron would gain negative charge so the electric force on it would change

Included a source of beta-radiation

Measuring *e*

Millikan found that the charges were all small multiples of a particular value, e

Measuring e

So, m_e *is now calculated* $\frac{e}{m_e}$ *and* e

Quantization of charge

The electric charge is quantized

which means

The charge must have a
value which is multiple of e