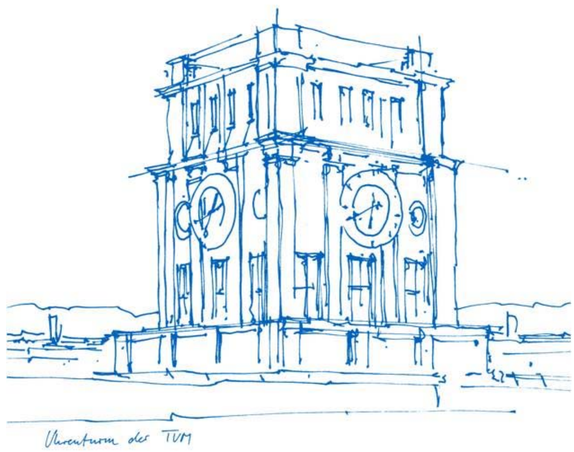
Lecture

Electricty and Magentism

- chapter 3.1: forces on moving charges in a magnetic field
- 3.1.1 Lorentz force and magnetic field



3.1 Forces on moving charges in a magnetic field

3.1.1 Lorentz force and magnetic field

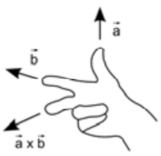
(i) Phenomenological observation: How do we recognize the presencde of a magnetic field?

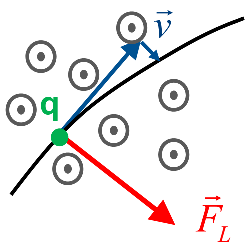
- by impact on moving electric charge
- deflection perpendicular to motion and to direction of magnetic field
  $\Longrightarrow$ force perpendicular to direction of motion = Lorentz force
- magnitude of force is proportional to
  - magnitude of velocity $\vec{v}$ of charge
  - charge q
  - magnitude of magnetic field

Lorentz force

$$\boxed{\vec{F}_L = q(\vec{v} \times \vec{B})} \quad (3.1)$$

right hand rule





Magnetic field points into plane
Magnetic field points out of plane

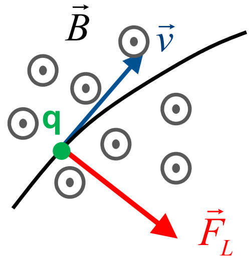
3.1 Forces on moving charges in a magnetic field
3.1.1 Lorentz force and magnetic field

Field quantity, which causes Lorentz deflection:

- magnetic
  magnetische induction/magnetic flux density, „B-field" $\vec{B}$
- unit: $\dim(\vec{B})=\frac{Vs}{m^2} = 1\,\text{Tesla} = 1\text{T}$

note: according to electric field, the effect of the force is described by a force field; see $\vec{F}_q = q\vec{E}$

Lorentz force $\vec{F}_L = q(\vec{v}\times\vec{B})$



(ii) If additionally an electric field is present:
Superposition of forces $\Longrightarrow$ electromagnetic force: :

$$\boxed{\vec{F}_{em} = q(\vec{E}+\vec{v}\times\vec{B})} \qquad (3.2)$$

3.1 Forces on moving charges in a magnetic field
3.1.1 Lorentz force and magnetic field

(iii) Work carried out in magnetic field:

- In electric field $\quad dW_{el} = \vec{F}_{el}d\vec{r} = q\vec{E}d\vec{r}$
- Im magnetic field $\quad dW_{mag} = \vec{F}_L d\vec{r} = q(\vec{v}\times\vec{B})d\vec{r} = q(\frac{d\vec{r}}{dt}\times\vec{B})d\vec{r}$

$\perp \vec{F}_L$

and power: $\quad P_{mag} = \frac{dW_{mag}}{dt} = q(\vec{v}\times\vec{B})\frac{d\vec{r}}{dt} = q(\vec{v}\times\vec{B})\vec{v} = 0$

$\perp \vec{v}$

No work is done on electric charge in a magnetic field; no power is added (as far as no electric field is present)

$\Longrightarrow$ kinetic energy remains constant, and, hence, also the magnitude of the velocity:
$|\vec{v}|$=const. $\Leftrightarrow \frac{d\vec{v}}{dt} = 0$ (not direction! Direction is changed!)

(note: $\vec{v} \backsim \vec{E}$ for drift model)