1) Introduction

current opinion today on magnetic monopoles

2) Ehrenhaft’s Experiments

historical
the Ehrenhaft - Millikan disput
basic experimental setup & particle production
exp. methods: Stokes-Cunningham
optical methods
mechanical methods

“light pressure” phenomena:
  positive photophoresis
  negative photophoresis
  gravitophoresis
  photophoretic figures

electrophoresis: proof, v-E- diagram
electronic charge: “Millikan’s proof”
magnetophoresis: definition, proof
  mixed effects
  does the electronic charge exists?
magnetic charge: experiments on
  particles
  in gas discharges
  in liquids
  in radioactive decay

3) Magnetic Monopoles in Classical Electrodynamics

4) Conclusion
1. Introduction

The current scientific opinion says:
experimentally:
there exist no significant proofs on
magnetic monopole charges

theoretically:
1) magnetic monopoles behave acc. to Dirac’s prediction, i.e.
\[
\frac{ge}{\hbar c} = \frac{n}{2}
\]

2) electric and magnetic fields have the following symmetries:
\[
\begin{array}{ccc}
\text{x --> -x} & \text{E} & -1 \\
& \text{D} & -1 \\
& \text{H} & 1 \\
& \text{B} & 1
\end{array}
\]
\[
\begin{array}{ccc}
\text{t --> -t} & \text{E} & 1 \\
& \text{D} & 1 \\
& \text{H} & -1 \\
& \text{B} & -1
\end{array}
\]

de facto:

experimentally:
magnetic monopoles were found
and seem to follow Dirac’s prediction

theoretically:
therefore, electromagnetic fields do not have
any symmetric preferences generally

practically and economically:
relevant with respect to calculation and design
of anisotropic magnetic materials and antennas
2. The Experiments of Felix Ehrenhaft

historical problem: how to measure forces on little particles?
to test the theories of
light pressure
electronic or magnetic charges

typical experimental setup:

production of particles: by electrical sparking of the wanted material
Measuring Forces on Microscopic Particles

method is indirect and needs

1) a measurement of the velocity of the particle
2) a measurement of the diameter of the particle

formulas:

\[ v = \mu F \quad \text{with} \quad \mu = \text{mobility} \]

\[ F = 6\pi \eta v \left[ 1 + \frac{1.63 llr}{f + 2(1-f)} \right] \quad \text{with} \quad \eta = \text{viscosity} \]

measurement of velocity : with microscope scale und stop watch

measurement of diameter (selection!):
using Mie-light diffraction
by a mechanic method
by fotography
Results of Experiments with Light Pressure

1) Einstein’s formula is wrong for high light intensities; values of $\mu$ determined acc. to Einstein are too high if compared with other methods applied by Ehrenhaft

$$\mu_{\text{Ehrenhaft}} < \mu_{\text{Einstein}} = \frac{\Delta x^2}{2kT}$$

with $\Delta x^2 = \text{mean square of deviation}$

$$k = \text{Boltzmann constant}$$

$$T = \text{temperature}$$

$\Delta x^2$-deviations between different methods are too big in the direction of light

2) the theory of light pressure of P. Debye is correct for the most particles, but not for all!

3) there exist “lightnegative” particles, which are attracted by light. The working colour is mostly in the blue. Probably these colours correspond to excited spectral lines!

light pressure on a sphere dependent from its radius for a wavelength of 700 µm on Ehrenhaft’s apparatus calculated acc. to P. Debye

experimental setup of Ouang Te Tchao to prove macroscopic negative-photophoretic force. The wings of the torsion pendulum contain a liquid of china perfume. The chamber is evacuated to high vacuum. This excludes thermic radiometer forces
4) the path is spiraling, if
   particle diameter \( \phi > \) wavelenght \( \lambda \)

5) there exists “Gravitophoresis” i.e.
   some particles move in the light beam against gravity

Gravitophoresis: the particles seem to lose their weight and are hanging at the upper border of the illuminating light beam.
sometimes they are moving up and down periodically; comp. left fig.
6) There exist highly complex “photophoretic” patterns of movements

Setup:

![Diagram of vacuum bulb setup]

- vacuum bulb to observe photophoresis
- a filament
- b vacuum c anode
- f dust material
- g to pumping line
- h deflection electrode

Conditions: $10^{-5} \rightarrow 50 \text{ mg Hg pressure}$, intensive (sun)-light has to be focused by a big lens ($\varnothing=10\text{-}20\text{ cm}$) in the inner of the vacuum bulb

A fine dust material ($\varnothing=10^{-3} \text{ cm}$) has to be used

typical “nice” pictures:

![Complex patterns of movement in photophoresis taken as snapshots with stroboscopic illumination (positives)]
The most important patterns of photophoresis

The most important toroids of photophoresis, comp. text

the particles are captured in the gradient of the light focus and move on a stable and closed path!

photophoretic toroidal path

photophoretic toroid during a day

frequency measurement of photophoretic toroids during a day
**Electrophoresis**

**Definition:** movement of charged particles in an electric field. The charge is generated by intense light. It dissapears instantaneously if the light is switched off.

**Observations:**

1) The movement of the particle commutes with the field (in most cases!)

2) The stronger the light, the bigger the effect.

3) Electrophoretic charges go down to 1/10 e.

4) Electrophoresis shifts the position of photophoretic toroids in a light focus.

5) The effects are not influenced by ionising radiation (γ- oder UV-Strahlung).

6) Useful materials ordered: Te, Sb, J > Ni, Fe, Se, Bi.

7) It exists an optimal gas pressure.

8) The saturation field of a particle is independent from pressure.

![Image of velocity vs. electrical field E of a electrophoretic charged particle. The saturation depends from the intensity.](image1.png)

![Image of velocity vs. lamp current for a Sb Particle under electrophoresis.](image2.png)
The electric Charge

Historical background: Ehrenhaft-Millikan disput:
Millikan stated to have seen e
Ehrenhaft said that this is not possible!

today we know:
Ehrenhaft was right - Millikan tuned his data!

Experimental setup:

Measurements:

without field: \( mg = \frac{v_1}{\mu} \)
with negative field: \( -eE + mg = \frac{v_2}{\mu} \)
with positive field: \( +eE + mg = \frac{v_3}{\mu} \)

after measurement the equations are solved for \( \mu \), m und e

Conclusion: the single electronic charge cannot be proved at this pressures with this method.

Histogramm of 74 charged oildrops from a student lab.
From: American Journal of Physics 40 (May 1972), 769

1/3-electronic charges on little supraconductive Niob spheres measured acc. to Fairbank's method
**Magnetophoresis**

Definition: movement of magnetic charged particles in a magnetic field. The magnetic charge is induced by the light and disappears instantaneously, if the light is switched off.

Experimental setup:

Observations: 1) magnetophoresis adds to photophoresis in the light
2) the particle follow the outer field acc. to unipolar charge

They can be deviated by a homogeneous magnetic field.
Observations:

1) linear or weak spiraling movements enlarge to full spiral in field. kinetic energy or velocity remains conserved.

2) the v-H diagrams are point-symmetric. The form of the Diagrams varies very strongly

3) it exists a fixed ratio $\frac{q_H}{q_E}$ which is empirical

$$\frac{q_H}{q_E} = \frac{E}{H} \frac{v_H}{v_E}$$

Dirac-value

experiment of V.F. Mikhailov

parallel velocity distribution of elektrophoretic (E) and magnetophoretic (M) charged particles
The magnetic Charge

Setup:
Fall experiment under stroboscope illumination

Observations:
1) particles fall with a screw movement without any electric charge

2) after switching on the field the particles jump around some seconds.
   -> Barkhausen - noise ????

left fig.15a and b falling copper particles in the magnetic field (7000 G) in 15b screwing path with \( \varphi = 1/8 \text{mm} \) and slope per tread 1.4 oder 0.6mm. fig.16 right side: explosion of Nickel particles on switching in 7000 Gauss under stroboscopic illumination.
3) “classical” monopoles under stroboscobe illumination

4) bursting of particle into magnetic monopoles

with conservation of momentum and charge
Monopoles in different environments

1) in light: magnetisation of iron by light is observed!
magnetisation explained by charging up with monopoles?

2) in gas discharges: all magnetic charge particles are produced in sparks!

3) in vacuum tubes: a) Righi’s magnetic rays

   setup: magnet in vacuum as cathode
   surface covered by with apiezon grease
   anode in space, 800V, 40mA, R=50000Ω

setup for observation “magnetic” rays
1 glass vessel, 2 glass window, 3 stopper, 5+7 anode, 4 cathode, 6 to pumping lines 8 magnetic cathode
Observations:

1) el. fields do not influence the radiation
2) light intensity ~ magnetic field
3) rays go through Alu if in magnetic field
4) rays originate from apiezon grease

5) plasma can be decomposed, however no exact results were available.
6) magn. rays not present in high vacuum
3) in vacuum tubes: b) Tesla’s oscillating plasma files

Observations:
at 10000Hz, and high voltage in a gas discharge - 1 plasma file
with additional magnetic field - splitting up in 2 files,
Oscillation after disturbance by magnetic fields or by approach of a hand

Interpretation (acc. to Freeman Cope): plasma file consists of monopoles

4) charged solid bodies with monopoles? (experiment of Freeman Cope)

Measurement of the (superweak) magnetic fields of hairs

<table>
<thead>
<tr>
<th></th>
<th>white hair</th>
<th>black hair</th>
</tr>
</thead>
<tbody>
<tr>
<td>at protonresonanzmagnetometer</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>at SQUID</td>
<td>8</td>
<td>2</td>
</tr>
</tbody>
</table>
5) Monopoles in Liquids?

“Charging” experiments or only slowly changes of chemical substances in a magnetic field???

solution von Oxygen in water in a magnetic field

change of the spectrum of absorption of Trypsin a magnetic-field

change of the spectrum of absorptions of water under a magnetic field
change of viscosity of water in magnetic field

viscosity of H2O in a magnetic field

change of electric resistance of water in a magnetic field

electric resistance of water in a magnetic field

change of surface tension of water in magnetic field

electric surface tension of water in a magnetic field

change of cristallites in water in a magnetic field

a similar phaenomen: different cristal modifications in water before and after a “vortex treatment”
6) fields of movement in liquids by magnetic field

FeCl - solution in a field of a magnet shows a rotation. the direction of rotation depends, whether the solution is acid or a base

\[ \text{\textgreater \textgreater \ experiment (base over acid or reverse)} \]

Reagents:

<table>
<thead>
<tr>
<th></th>
<th>HCl (6n)</th>
<th>HCl (6n)</th>
<th>HCl (6n)</th>
<th>HNO(_3) (6n)</th>
<th>H(_3)PO(_4) (6n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaOH (6n)</td>
<td>NH(_2)OH (6n)</td>
<td>KOH (6n)</td>
<td>KOH (6n)</td>
<td>KOH (6n)</td>
<td>KOH (6n)</td>
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<td>NH(_2)OH (6n)</td>
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<td>NH(_2)OH (6n)</td>
<td>NH(_2)OH (6n)</td>
</tr>
<tr>
<td>CH(_3)COOH</td>
<td>HJ (6.9n)</td>
<td>HJ (6.9n)</td>
<td>H(_2)SO(_4) (6n)</td>
<td>H(_2)SO(_4) (6n)</td>
<td></td>
</tr>
</tbody>
</table>

Setup:

Petri disks are positioned over magnets!

Observations:

- if acid is positioned over the base there arise rotations of the liquid, whose direction of rotation depends from the pH locally present

- for a rotation is necessary:
  1) a vertical gradient in acidity
  2) a magnetic field

- a temperature gradient can reverse the direction of rotation

- without magnetic field there exist no effect

- a semipermeable membran between base und acid does not prevent the effect!
7) magnetic monopoles in radioactive phenomena?

blackening of photoplates bei β-Strahlern is intensified, if they are in a magnetic field.
Interpretation: particles carry magnetic charges and are accelerated by the field.

setup to prove the enhancement of radioactive radiation by magnetic fields
3.) Magnetic Monopoles in Classical Electrodynamics

Magnetic monopole charges are necessary, because

\[ \text{div} \mathbf{B} = \text{div}(\mu(x) \mathbf{H}) - \mu \text{ div } \mathbf{H} + \mathbf{H} \text{ grad } \mu(x) + 0 \]

Consequences:

- magnetic fields are general fields without parity properties
- the causes of fields are always current and charges
- the magnetic boundary conditions have to be modified
- Constitutive relations are generally

\[
\begin{pmatrix}
\mathbf{\dot{D}} \\
\mathbf{\dot{B}}
\end{pmatrix} =
\begin{pmatrix}
f_1(\mathbf{E}, \mathbf{D}, \mathbf{H}, \mathbf{B}; T, \rho, x, \omega, \ldots')(x,t) \\
f_2(\mathbf{E}, \mathbf{D}, \mathbf{H}, \mathbf{B}; T, \rho, x, \omega, \ldots')(x,t) \\
f_3(\mathbf{E}, \mathbf{D}, \mathbf{H}, \mathbf{B}; T, \rho, x, \omega, \ldots')(x,t)
\end{pmatrix}
\]

- \( \rightarrow \) In order to solve the problem the PDE-System of Maxwell equations has to be completed by thermodynamic, mechanic and other PDE-equations from the other areas of physics
- old magnetic vector potential \( \mathbf{A} \) alone does not work generally!
  \( \rightarrow \) general magnetic fields have to be derived from a vector potential and a magnetic potential due to magnetic charges
- practical applications: antenna with anisotropic cores
  simulation of and with permanent magnets
4.) Conclusion

Electromagnetic forces may have some interesting, unexploited features as

- negative photophoresis
- gravitophoresis
- photophoretic figures
- spiral movement
- magnetophoresis
- magnetic monopoles

magnetic monopoles seem to be necessary even in conventional electric engineering to cover all cases in magnetic field calculations

magnetic effects can play a big role in chemistry