Faraday balance magnetometer

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Ways of measuring magnetic susceptibility

Magnetic susceptibility is a measure of a materials response to magnetic field.

diamagnetic materials: $-1 < \chi < 0$
paramagnetic materials: $0 < \chi \ll 1$

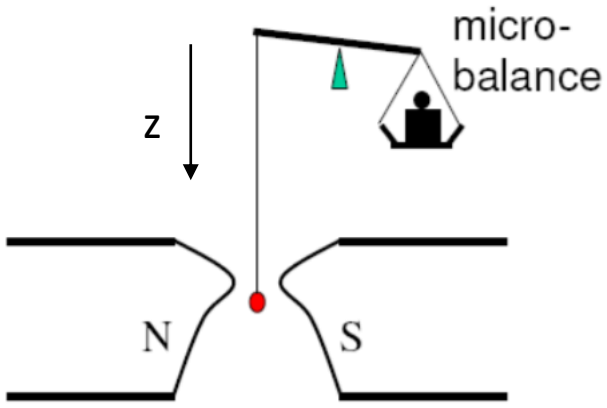
Force method
- Gouy method
- **Faraday method**
- Alternating Force Magnetometer (AFM)

Induction method

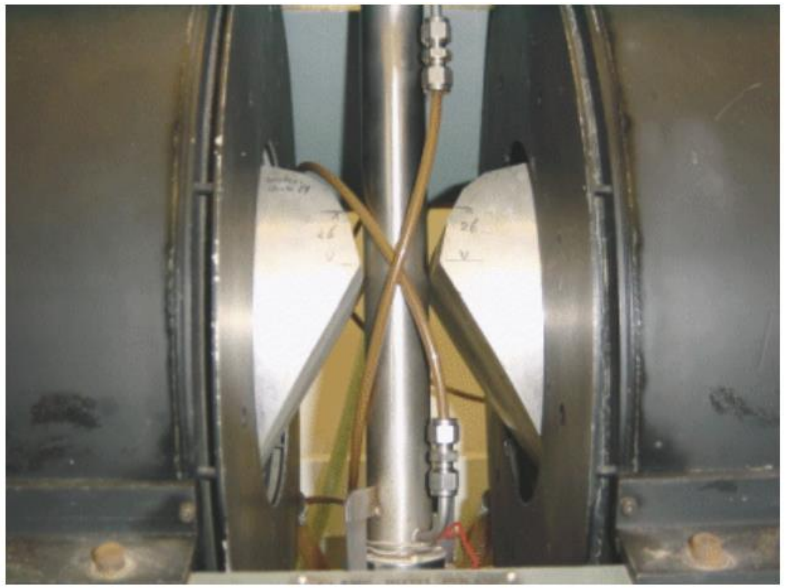
O'Connor, C.J. (1982). Lippard, S.J., ed. Magnetic susceptibility measurements. Progress in Inorganic Chemistry. **29**. Wiley. p. 203. ISBN 978-0-470-16680-2.

Principle and schematic

- A sample is attached to an analytical balance and suspended from it.
- The sample is placed (suspended) in between poles of magnet in a region of magnetic field gradient where H(dH/dz) is constant over the volume of the sample.
- The mass of the sample is taken with and without the magnetic field.
- The difference in mass of the sample with and without the magnetic field corresponds to magnetic susceptibility of the sample.
- $F = \chi_m mH(dH/dz)$ where $\boldsymbol{\chi_m}$ is magnetic susceptibility per unit mass and **m** is mass of the sample.



Schematic of Faraday Balance



Photograph of the Faraday pole caps.

Prof. Ruslan Prozorov: Magnetic Measurements Part I - Basics.

O'Connor, C.J. (1982). Lippard, S.J., ed. Magnetic susceptibility measurements.

J. C. P. Klaasse, Van der Waals-Zeeman Institute, november 1999.

Example

Faraday Balance for Measuring Magnetic Susceptibility*

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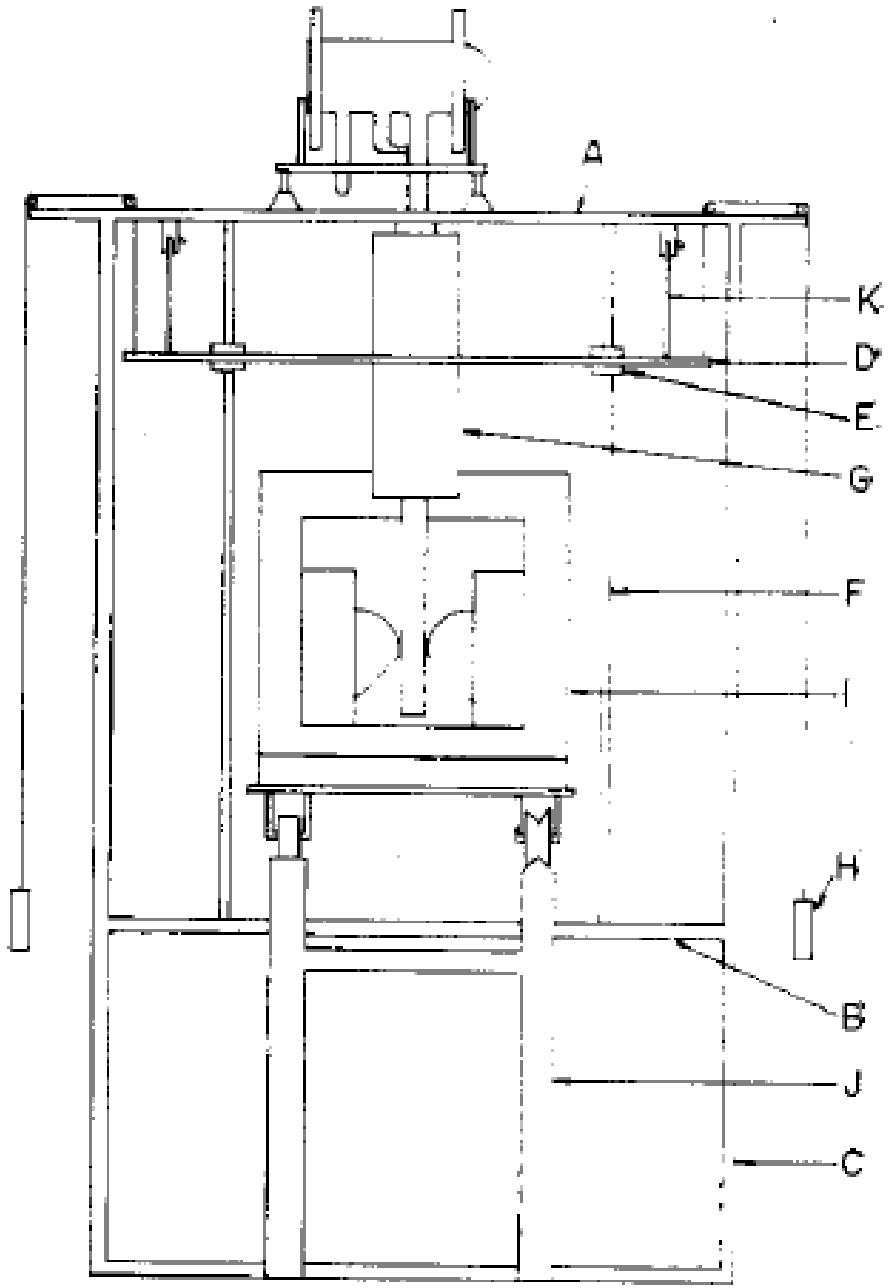
(Received 9 July 1968; and in final form, 6 August 1968)

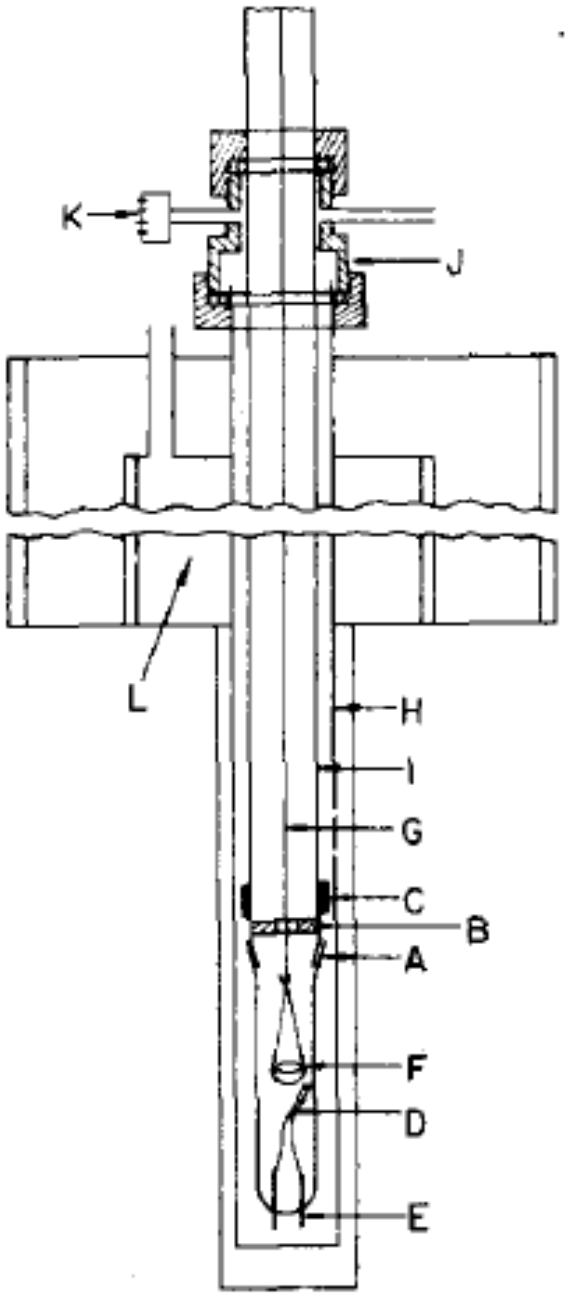
An apparatus for measuring magnetic susceptibility by the Faraday method is described. It is capable of measuring susceptibilities ranging from 0.01×10^{-6} to 500×10^{-6} emu/g over a temperature range of 5 to 300 K, in fields up to 10 kOe, with a precision of 0.2% and an accuracy of 1%. Various problems associated with the measurements, such as thermomolecular flow, ferromagnetic impurities, and electrostatic forces, are discussed. It is shown that problems arising from thermomolecular flow can be avoided by controlling the pressure of exchange gas. Correction for ferromagnetic impurities involves extrapolating the susceptibility vs $1/H$ to infinite field. Several methods for minimizing the problems caused by electrostatic force are discussed. The versatility of the balance is demonstrated by measurements made on $NiTiO_3$ ($\chi_{max}=229\times10^{-6}$ emu/g) and $K_{0.3}MoO_3$ ($\chi\approx0.06\times10^{-6}$ emu/g).

Schematic diagram of apparatus.



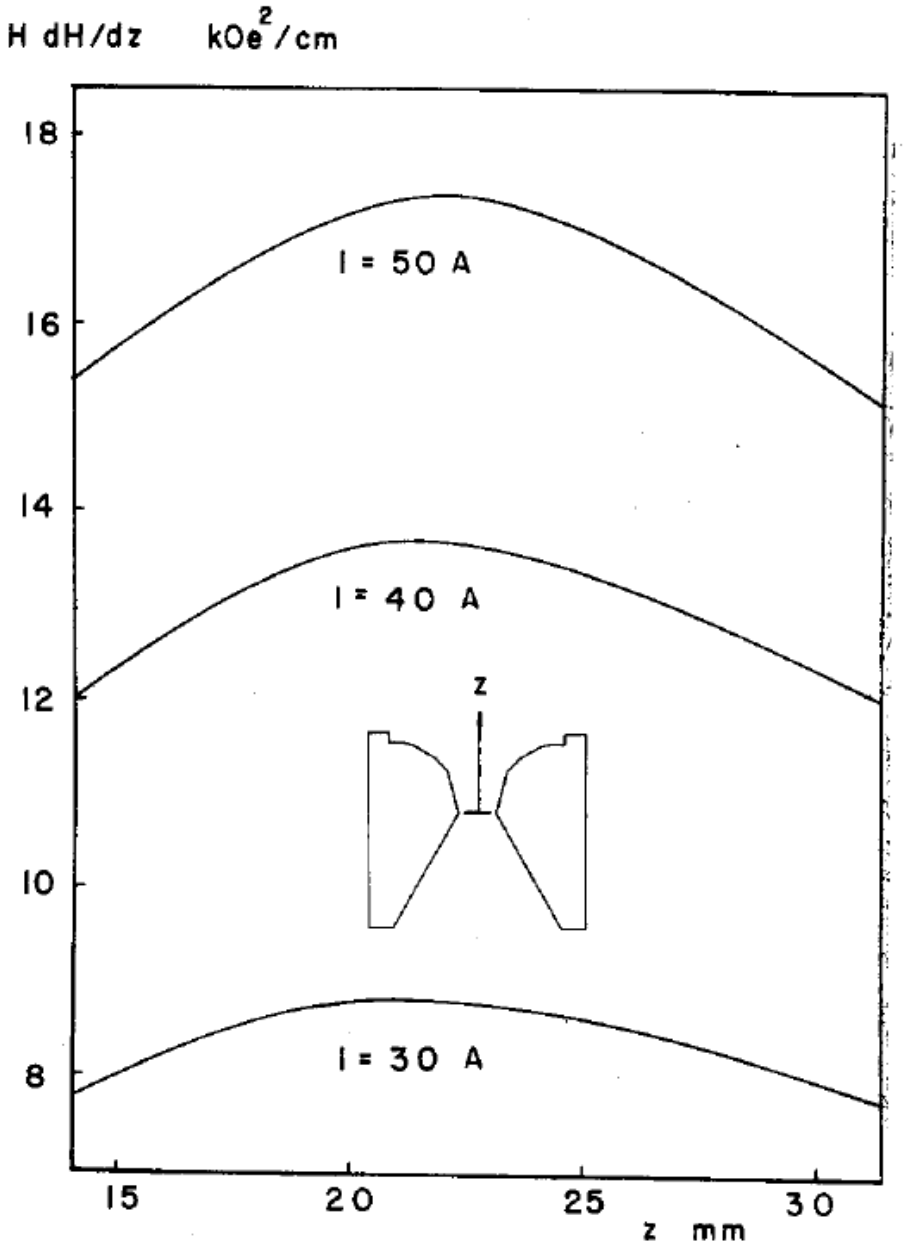
<u>Important components</u>

A and B are aluminum platforms
C is the steel frame
G is the stainless steel dewar
H is the counter weight
I is a magnet rolling on steel track J

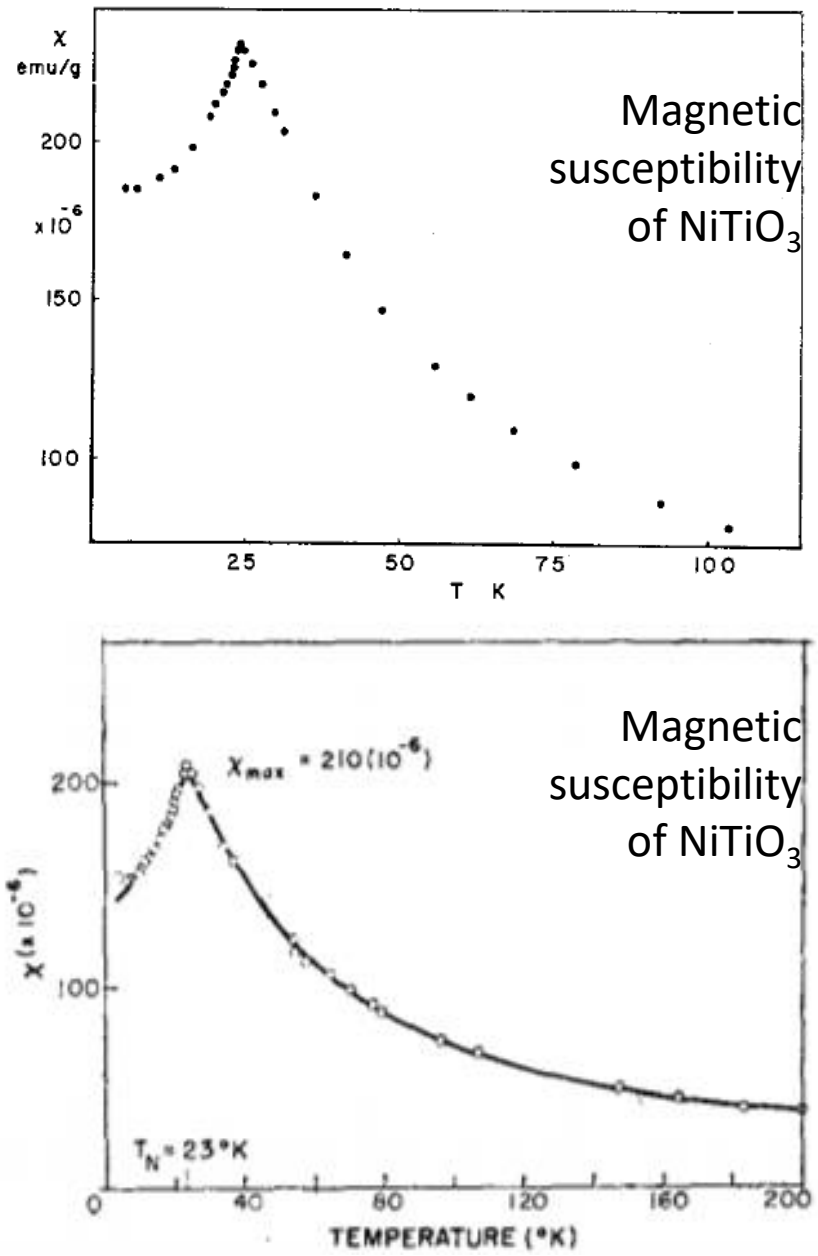


Important components

- A – pyrex joint
- B – brass radiation baffle
- C – heater
- D – platinum resistance thermometer
- E – tungsten rods
- F – sample bucket made of fused silica
- G – silica fiber
- H – inner tail
- I – pyrex tube
- J – is used to join H and I
- K – vacuum feed through



Magnetic force vs position along vertical axis. Ideal position is at 21 mm.



G. S. Heller, J. J. Stickler, S. Kern, and A. Wold, *J. Appl. Phys*. 34, 1033 (1963).

Conclusion

- Faraday method of measuring magnetic susceptibility is better than Gouy method because a small amount of sample can be used and one does not need to worry about uniform packing of sample.

Thank you
Questions?