



## HALL EFFECT APPARATUS



**SKU:** frm-hall-ge



## PRODUCT DESCRIPTION

### Fermium's Hall Effect Apparatus

The most advanced didactical apparatus on the market. Thanks to the bleeding-edge electronics and the 300°C temperature range, you can take measurements otherwise impossible:

- **Hall voltage  $V_H$  vs.  $T$  and  $B$**
- **Hall Mobility  $\mu_H$  vs.  $T$**
- **Resistance vs. Temperature**
- **Evaluation of dopant density  $N_a$**
- **Energy gap  $E_g$  linearly extrapolated to  $T=0K$**
- **Mobility ratio  $b=\mu_e/\mu_h$**
- **Earth magnetic north pole**

### Introduction:

The Hall effect is fundamental in the investigation of material properties because it allows direct measurements of the free carriers concentration, and it's sign, both in metals and in semiconductors.

The Hall effect is also technologically relevant. It's the working principle behind the magnetic field sensors in every smartphone, MacBook and iPad.

The Hall effect essentially is due to the Lorentz force  $F$  acting on each electric charge  $q$  moving with velocity  $v$  in a magnetic field  $B$ .

Here's a wonderful video by the popular Youtube channel Sixty Symbols, where Professor Bowley explains it flawlessly:

This apparatus solves in advance a great number of challenges that would impair the correct experiment and take months to sort out:

- Sourcing, cutting and polishing a sample with the appropriate parameters to conduct the experiment successfully
- Stable ohmic electrical contacts to the sample
- Isothermal environment for the sample avoiding thermal gradients
- Controlling the temperature in a wide range -150°C to +150°C
- Providing a stable and precise constant-current to the sample
- Providing a variable, stable, and uniform magnetic field to the sample
- Keeping self-heating due to the bias current to a minimum
- Providing adequate amplification to all the signals with a variable/programmable gain
- Measuring the magnetic field
- Keeping in check errors:
  - Microphonic pickup of the sample wiring inside the magnetic field
  - Uneven magnetic field
  - Uneven thermal gradients
  - Seebeck effect
  - Parasitic Schottky diodes on the samples and the likes
  - Amplifier drift, offset
  - Unbalanced bias currents of the differential amplifiers
  - Reference voltage stability and precision
  - Constant current generator drift and precision
  - ...
- Providing a mean to compensate for imperfections in the sample contact positioning that would overwhelm the delicate  $V_h$  signal
- Measure the resistance of the sample through a 4-wire measurement system



- Measuring the sample temperature precisely (not easy at cryogenic temperatures)
- Shutting down the heater when required to avoid damage
- Safe power supply
- Providing adequate shielding to the measurement to avoid noise pickup

## Evolution

This apparatus is a 5th generation model:

- 1st and 2nd generation from 1990 to 2015
  - 3rd from 2015 to 2017
  - 4th from 2017 to 2019
  - 5th 2019+

## Specifications:

### Electronics:

- Compact and all-in-one
- 5-point hall voltage measurement with virtual center point balance (to compensate for the sample contact positioning)
  - balanced Hall voltage output, unbalanced Hall voltage output 1, unbalanced Hall voltage output 2
- High precision amplifier stages for  $V_h$ ,  $V_r$ :
  - 10uV offset voltage
  - 1 to 4096 programmable gain with 0.1% precision
  - 1.5nA input bias current
- Gaussmeter probe with 5% precision, variable gain from 1 to 4096, stable 1mA bias current supply
- Two power-level heating system
- Stable 0-20mA constant bias current generator with 0.1% readout on a 0-5V output
- Lock-in modulation input
- 12V 45W power supply
- Grounding plug/crocodile clip
- K-type thermocouple with cold-point compensation circuitry
- Safety 150°C heater cut-out with 100°C alarm reset
- Safety alarm at 60°C HOT - do not touch! with blinking LEDs
- Retention of the configured parameters

### Mechanics:

- Variable magnetic field
  - Permanent rare-earth magnets
  - Up to approx. 0.5T field
  - soft-iron toroid
- -150°C to 150°C with liquid nitrogen and internal heater
- Anodized aluminum base and supporting rods

### Accessories:

- Gaussmeter probe
  - 1mA bias current
  - up to 5T measurement
- Gaussmeter positioning jig: allows the positioning of the gaussmeter probe at the center of the sample

## Included in the kit:

- Aluminum base and holder



- Permanent magnets and soft iron toroid with a variable magnetic gap
- Isothermal sample holder with heater, thermocouple, cold finger, Ge-P sample
- Stainless steel dewar (for liquid nitrogen or acetone+cold ice)
- Advanced electronics with variable gain, high-impedance, low noise, low drift, low bias current differential amplifiers; constant current generator, gaussmeter control circuitry, heater control circuitry, thermocouple circuitry
- Gaussmeter probe and connection wire
- Gaussmeter positioning jig
- Two DE-15 to 5-BNC cables
- 12V 45W power supply
- Digital Handbook

**Needed (not included in the kit) :**

- Datalogger (recommended Interface LabPro or equivalent)

**Innovative Handbook:**

- PDF for printing and HTML for projection in the classroom with variable font size, background color.
- [Open source](#): The professor/student can contribute feedback and modifications to the handbook
- Included interactive data analysis with open-source R language