

Vibrating Sample Magnetometry

Theoretical principle

Faraday's law of induction

$$V(t) = -\frac{d\phi_B}{dt} \quad (1)$$

$$\phi_B = \iint_S \vec{B}(\vec{r}, t) \cdot d\vec{A} = BS \quad (2)$$

$$\Rightarrow V(z, t) = -NS \frac{dB}{dz} \frac{dz}{dt} \quad (3)$$

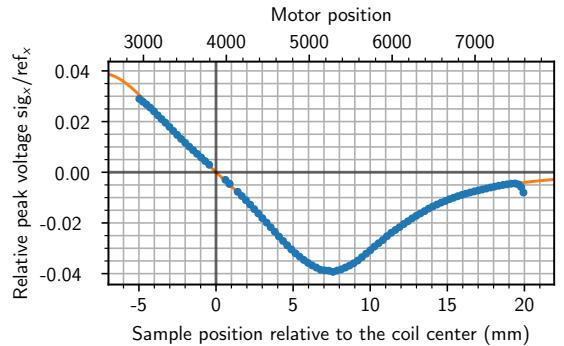
Magnetization

- **Paramagnetism:** Magnetic moment of unpaired electrons
- **Diamagnetism:** Lorentz force on electrons in orbitals

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One pickup coil, permanent magnet: 30.9 mg



Theoretical principle

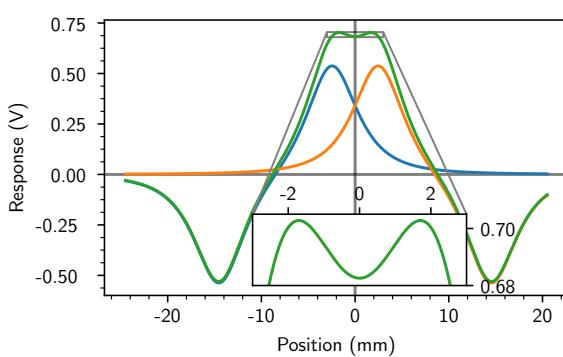
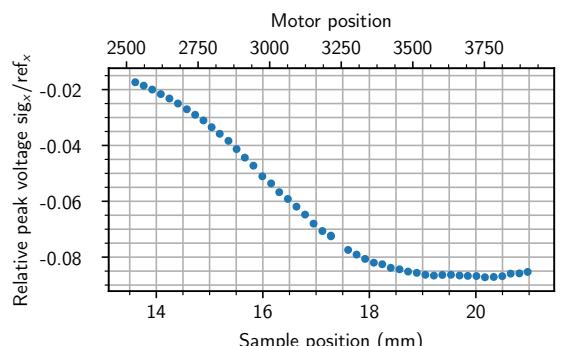
Induction on one pickup coil

$$V(z) = -NASI \mu_0 \frac{f\pi}{\sqrt{2}} \left[\ln \left(r_2 + \sqrt{r_2^2 + (z-L)^2} \right) - \ln \left(r_1 + \sqrt{r_1^2 + (z-L)^2} \right) + (z-L)^2 \left(\frac{1}{r_2 \sqrt{r_2^2 + (z-L)^2} + r_2^2 + (z-L)^2} - \frac{1}{r_1 \sqrt{r_1^2 + (z-L)^2} + r_1^2 + (z-L)^2} \right) + \ln \left(r_1 + \sqrt{r_1^2 + z^2} \right) - \ln \left(r_2 + \sqrt{r_2^2 + z^2} \right) + z^2 \left(\frac{1}{r_1 \sqrt{r_1^2 + z^2} + r_1^2 + z^2} - \frac{1}{r_2 \sqrt{r_2^2 + z^2} + r_2^2 + z^2} \right) \right] \quad (4)$$

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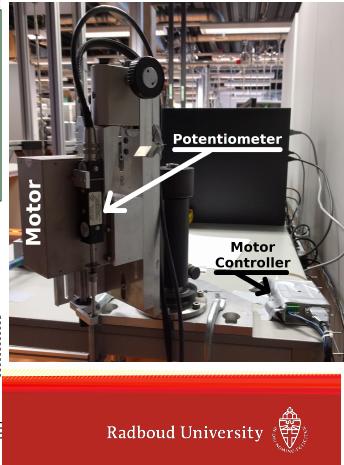
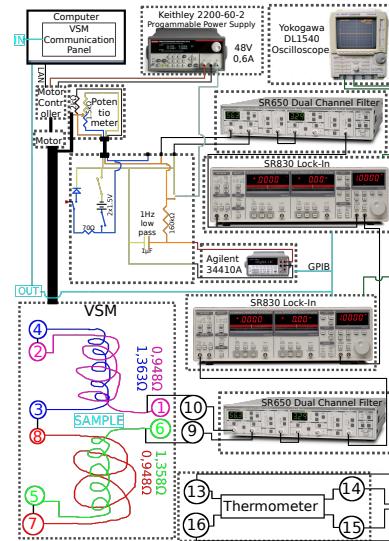
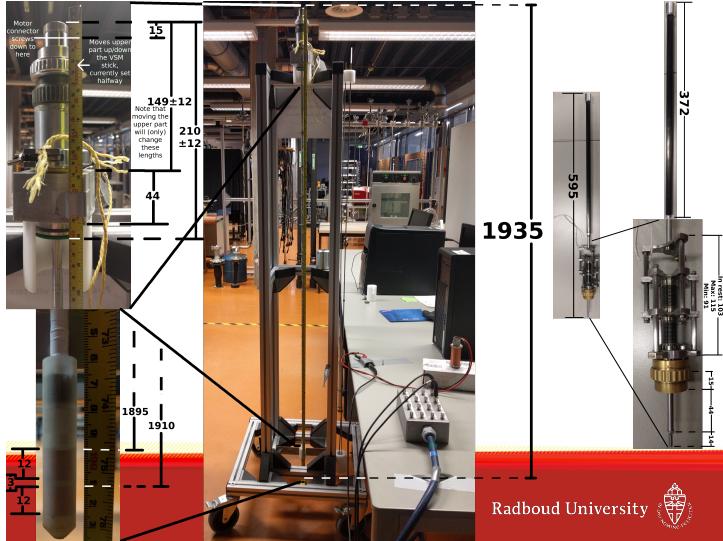
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All 4 pickup coils, Nickel: 42.5 mg at 2 T (Room Temperature)

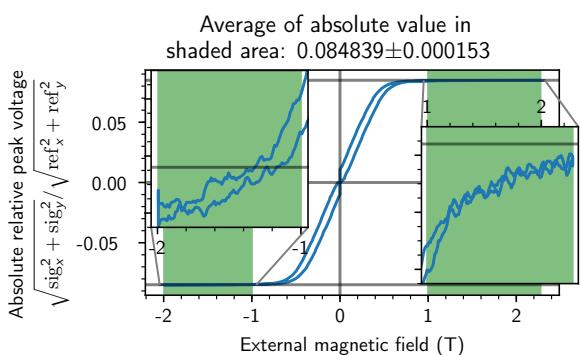


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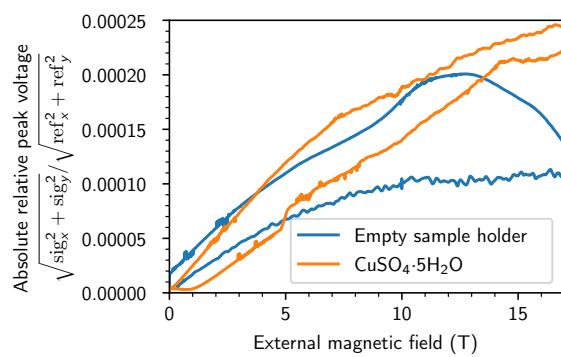


Nickel: 42.5 mg (**Room Temperature**)
 $(58.57 \pm 0.03) \text{ emu/g} \implies (2.489 \pm 0.002) \text{ emu} \implies c = (29.34 \pm 0.06) \text{ emu}$



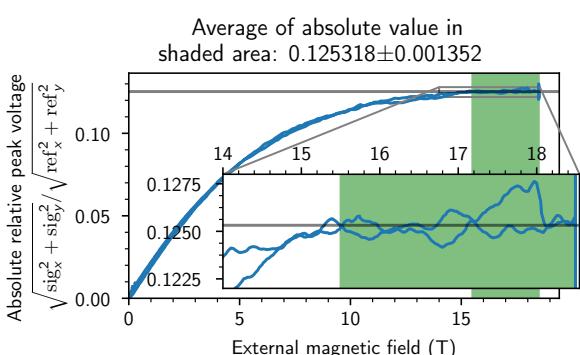
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CuSO₄·5 H₂O: 143 mg (**Room Temperature**)



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CuSO₄·5 H₂O: 143 mg (**4 K**)
 $c = (29.34 \pm 0.06) \text{ emu} \implies (3.67 \pm 0.04) \text{ emu} \implies (25.7 \pm 0.3) \text{ emu/g}$



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Sanity Check

- Paramagnetic Cu²⁺ ions: Spin 1/2
- $2\sqrt{s(s+1)} = \sqrt{3} \mu_B$
- CuSO₄·5 H₂O: 249.684 u
- $\implies 39 \text{ emu/g}$
- Diamagnetic contributions of H₂O and SO₄²⁻

More info:

github.com/AndrewAmmerlaan/HFML-VSM_CoilProfilePlotter

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