1. Experimental Contents

1) Measure weak magnetic fields using a magnetoresistive sensor
2) Measure the sensitivity of a magneto-resistance sensor
3) Measure the horizontal/vertical components of the geomagnetic field and its declination
4) Calculate the geomagnetic field intensity.

2. Precautions

1) Avoid the presence of a strong magnetic field or ferromagnetic materials near the setup.
2) Two Helmholtz coils must be wired in series (i.e. connect the red terminal of one coil to a black terminal of the other coil using a black banana plug wire).
3) For measuring horizontal component of the geomagnetic field, set the small rotational stage (sensor) to horizontal plane, place the level indicator onto the stage, and adjust the two feet of the base to level the small stage. For measuring vertical component of the geomagnetic field, place the small stage in vertical plane and set its surface in the meridian plane of geomagnetic field.
4) Magnetoresistive sensor is a delicate device, so one must handle it with care to avoid damage.

3. Experimental Procedures

1) Measure the sensitivity of a magneto-resistance sensor

   a) Wire connection: Connect the current source to the Helmholtz coils using banana plug wires. The positive (+) output of the "Const. Current" is connected to the Red terminal of one coil and the negative (-) output is connected to the Black terminal of the other coil. Then use the other black banana plug wire to connect the remaining black terminal and red terminal of the two coils to make the two coils connecting in series. Connect the terminal "Sensor" to the 7-pin socket on the coil base using the 7-pin cable.

   b) Set the "Adj." knob of "Const. Current" counterclockwise to minimum. Then turn on power and preheat the unit for 15 minutes.

   c) Rotate the small stage using the knob underneath to align the two indication marks on the inner disk to the "Zero" scales on the outer disk by making the sensor pin parallel to the magnetic field of Helmholtz coils, so that it can measure the uniform magnetic field of the Helmholtz coils on its central axis.

   d) Adjust the "Adj." knob of the "Const. Current" to zero the output current while adjusting the "Zero" knob of "Measurement" block to zero the voltmeter reading of the sensor.

   e) Adjust the output of the "Const. Current" (i.e. magnetization current) to change the strength of magnetic field while recording the voltage reading of the sensor at the corresponding current value. Note, push "Reset" button once before recording voltage reading for each forward (or reversed) current value.

f) Use the magnetic field generated by the Helmholtz coils to acquire the sensitivity K of the magnetoresistive sensor by referring to Section 7 for details.

2) Measure the horizontal component of the geomagnetic field

a) Disconnect the three banana wires between the Helmholtz coils and the electric unit.

b) Remain the indication marks on the small stage at "Zero" positions.

c) Rotate the large stage horizontally to find the direction of the maximum voltage output of the sensor.

d) Fix the lock screw on the large disk. Adjust the feet of the base plate to make the small stage to level with a level indicator. Now, it is in the direction of the horizontal component $B_{//}$ of the geomagnetic field. Record the output voltage U_1 of the sensor.

e) Rotate the small stage to find the minimum voltage U_2 of the sensor output.

f) Use formula $|U_1 - U_2|/2 = KB_{//}$ and K (obtained in above experiment) to acquire the horizontal component $B_{//}$ of the local geomagnetic field.

3) Measure the vertical component, total strength and declination of the geomagnetic field

a) Per the previous experiment. Now, set the small stage in vertical plane to make the surface of the small stage in the meridian plane of the geomagnetic field.

b) Rotate the small stage to find the maximum voltage output U_1' and minimum voltage output U_2' of the sensor. Use $\left|U_1' - U_2'\right|/2 = KB$ to calculate the total strength B of the geomagnetic field.

c) When the maximum voltage output of sensor is found, record the angle between the indication mark of small stage and the horizontal plane as the inclination angle β of the geomagnetic field. **Note**: repeat measurements and use an averaged angle value.

d) Use $B_{\perp} = B\sin\beta$ to calculate the vertical component of the geomagnetic field.

4. Example of Data Recording and Processing

Note: following data are for reference purposes only, not the criteria for apparatus performance:

Helmholtz coils: for N=500, R=100 mm, $\mu_0=4\pi\times10^{-7}$ T·m/A, the magnetic field strength at the center of the Helmholtz coils axis is (two coils connected in series):

$$B = \frac{8\mu_0 \mathrm{NI}}{\mathrm{R}5^{3/2}} = \frac{8\times4\pi\times10^{-7}\times500}{0.100\times5^{3/2}}\times I = 44.96\times10^{-4} I$$

where B is the magnetic field strength in unit of T (Tesla), and I is the current flowing through the coils in unit of A (Ampere).

A. Measuring sensitivity K of the magnetoresistive sensor

In Table 1, the forward output voltages U_1 and U_2 refer to the measured output voltage of the sensor when the magnetization current is in the positive and reversed directions, respectively. thus, the mean output voltage is $\overline{U} = (U_1 - U_2)/2$. By averaging the forward and reversed output voltages, the influence of horizontal component of the geomagnetic field is eliminated. **Note**: push the red "Reset" button once before taking each voltage reading.

Table 1 Data of measuring sensor sensitivity

Magnetization Current (mA)	Magnetic Field Strength **B** ($\times 10^{-4}$ T)	U (mV)		Averaged U (mV)
		Forward U_1 (mV)	Reversed U_2 (mV)	
10.00	0.4496	1.92	-1.91	1.915
20.00	0.8922	3.84	-3.85	3.845
30.00	1.3488	5.82	-5.87	5.845
40.00	1.7984	7.79	-7.90	7.845
50.00	2.2480	9.72	-9.90	9.810
60.00	2.6976	11.67	-11.94	11.805

By curve-fitting the *B*~*U* data in Table 1, the sensitivity of the magnetoresistive sensor is obtained as $K = 43.619$ V/T, as shown in Figure 6.

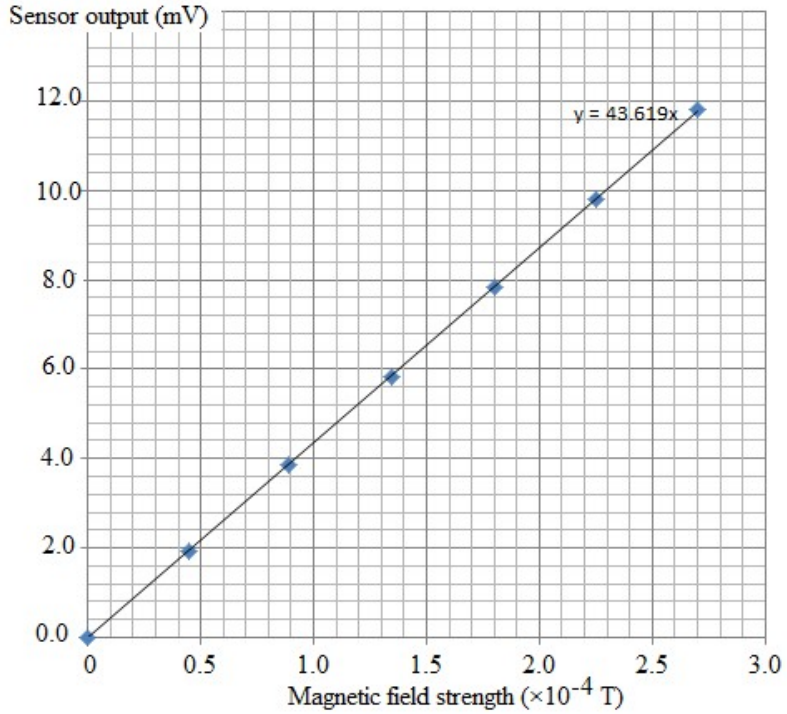

Figure 6 Plot of *B* vs *U*

B. Measuring horizontal component, vertical component and total geomagnetic field

(1) Measure the horizontal component of the geomagnetic field: maximum output voltage U_1 and minimum output voltage U_2 are recorded in Table 2. The calculated horizontal component of geomagnetic field is $B_{//} = 0.301\times10^{-4}T$.

Table 2 Measuring horizontal component of the geomagnetic field

U_1 (mV)	1.35	1.36	1.36	1.36	1.37	Average $U=(U_1-U_2)/2$ = 1.325 (mV)	$B_{//}$=0.301×10^{-4} T
U_2 (mV)	-1.28	-1.29	-1.29	-1.31	-1.29		

(2) Erect the small stage by the turning direction of the small stage in the meridian plane of the geomagnetic field. Rotate the small stage, while recording the maximum voltage output U_1' and minimum voltage output U_2' of the sensor in Table 3. Use $\left|U_1' - U_2'\right|/2 = KB$ to calculate the total strength B of the geomagnetic field, we got B =0.425×10^{-4} T.

Table 3 Measuring the total geomagnetic field

U_1' (mV)	1.90	1.91	1.91	1.91	1.90	Average $U'=(U_1'-U_2')/2$ =1.875 (mV)	B =0.425×10^{-4} T
U_2' (mV)	-1.83	-1.84	-1.83	-1.85	-1.84		

(3) Record the angle of small stage as the inclination angle of the geomagnetic field when sensor output is at the maximum. The angle must be measured multiple times around the maximum voltage point and take an average. Data are shown in Table 4.

Table 4 Data of measuring inclination angle β of geomagnetic field

β ($^\circ$)	42.0	43.0	44.0	45.0	46.0
U (mV)	1.90	1.91	1.91	1.91	1.91
β ($^\circ$)	47.0	48.0	49.0	50.0	51.0
U (mV)	1.91	1.91	1.91	1.90	1.90

From the data in Table 4, we got inclination angle $\overline{\beta} = 46.00^0$. Thus, the vertical component of the geomagnetic field is calculated as $B\times sin(46°) = 0.306\times10^{-4}$ T.