STUDYING MAGNETORESISTANCE AND HALL EFFECT OF BISMUTH

Aritra Mukhopadhyay
National Institute of Science Education and Research
Bhubaneswar, Odisha 751005, India
3rd year, Integrated M.Sc. Physics
Roll No.: 2011030
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In this experiment we will study the various solid properties of Bismuth like Magnetoresistance and Hall Effect.

Magnetoresistance: When the magnetic field is turned on, the resistance of a sample varies. Magnetoresistance is a material's capacity to alter the value of its electrical resistance when subjected to an external magnetic field. The amplitude of the impact is fairly small ($\approx 1\%$) at normal temperature, but increases to roughly 50% at low temperatures in gigantic magneto resistive multilayer systems. In certain perovskite systems, effects of more than 95% change in resistivity have recently been discovered.

Hall Effect: The Hall effect is the phenomenon of appearance of a potensial difference perpendicular to the direction of curent flow if a perpendicular magnetic field is applied. In the operating region, the Hall effect is a linear effect, which means that the voltage is proportional to the current and the magnetic field. The Hall coefficient is a measure of the Hall effect. It is defined as the ratio of the Hall voltage to the product of the current and the magnetic field. The Hall coefficient is a material property and is independent of the geometry of the sample.

I. THEORY

A. Magnetoresistance

Under the influence of a magnetic field, the resistance of some materials change significantly. This effect is popularly known as magnetoresistance of the material. This effect can be observed due to the fact that the drift velocity of the carriers is not same. In the presence of the Magnetic field, the carriers drift in the direction of the field. In this condition, the hall voltage compensates the lorentz force for carriers with average velocity. The slower carriers are overcompensated and the faster carriers are undercompensated. This disturbs the flow of electrons along the direction of flow of current; hence reducing the mean free path and increasing the resistance of the material. In this condition, the hall voltage is given by the formula:

$$V = E_y t = |v \times H|$$

where E_y and H are the electric field and the magnetic fields, t is the thickness of the sample, and v is the drift velocity of the carriers.

The change in resistivity $\Delta\rho$ is positive for both magnetic field parallel $\Delta\rho_\parallel$ and transverse $\Delta\rho_T$ to the current direction with $\rho_T > \rho_\parallel$. There are three different kinds of magnetoresistance, depending on the structure of the electron orbitals at the Fermi surface:

1. The magnetic field has the effect of raising the cyclotron frequency of the electron in its confined orbit in metals with closed Fermi surfaces where the electrons are restricted to their orbit in k-space.
2. The magnetoresistance for metals with an equal number of electrons and holes rises with magnetic field up to the highest observed fields and is unaffected by crystallographic orientation. These materials include bismuth.
3. In some crystallographic orientations, Fermi surfaces with open orbits will show significant magnetoresistance for applied fields, but the resistance will saturate in other crystallographic directions where the orbits are closed.

B. Hall Effect

The Hall effect is the production of a voltage across a conductor when an electric current is passed through it. The Hall voltage is proportional to the current density and the magnetic field perpendicular to the current. The Hall voltage is given by the formula:

$$V = E_y t = |v \times H|$$

where E_y and H are the electric field and the magnetic fields, t is the thickness of the sample, and v is the drift velocity of the carriers.

The Hall effect is a direct consequence of the Lorentz force on the charge carriers in a magnetic field. The Hall effect is a linear effect, meaning that the Hall voltage is proportional to the current density and the magnetic field perpendicular to the current. The Hall coefficient is the ratio of the Hall voltage to the product of the current density and the magnetic field perpendicular to the current. The Hall coefficient is a material property and is independent of the applied current density and the magnetic field. The Hall coefficient is a measure of the mobility of the charge carriers in the material. The Hall coefficient is given by the formula:

$$R_H = \frac{V}{I \times B}$$

where V is the Hall voltage, I is the current density, and B is the magnetic field perpendicular to the current. The Hall effect is a linear effect, meaning that the Hall voltage is proportional to the current density and the magnetic field perpendicular to the current. The Hall coefficient is the ratio of the Hall voltage to the product of the current density and the magnetic field perpendicular to the current. The Hall coefficient is a material property and is independent of the applied current density and the magnetic field. The Hall coefficient is a measure of the mobility of the charge carriers in the material. The Hall coefficient is given by the formula:

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II. OBSERVATION AND ANALYSIS

A. Magnetoresistance

1. I=198.5mV

table 1.

2. I=101.0mA

Table.2

B. Hall effect

I=197.3mA
Room temperature=25° C
Thickness(z)=0.5mm

Table.3

H(gauss)	Voltage(mv)	Resistance	deltaR/R
0	0.036	0.000183861	0
390	0.037	0.000188968	0.026291892
2410	0.038	0.000194076	0.051915789
3480	0.041	0.000209397	0.121287805
4090	0.043	0.000219612	0.16215814
4380	0.044	0.000224719	0.1812
4520	0.046	0.000234934	0.2168
4560	0.048	0.000245148	0.249433333
4700	0.049	0.000250255	0.26475102
4920	0.05	0.000255363	0.279456
5060	0.051	0.00026047	0.293584314
5130	0.052	0.000265577	0.307169231
5290	0.053	0.000270684	0.320241509
5360	0.054	0.000275792	0.33282963

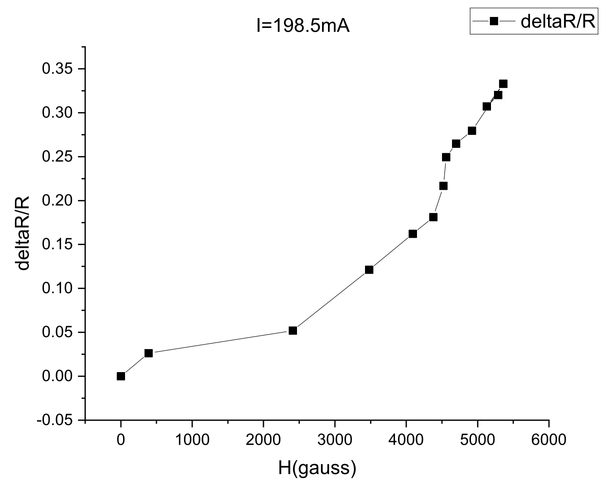

FIG. 1: $(\Delta R)/R$vs H

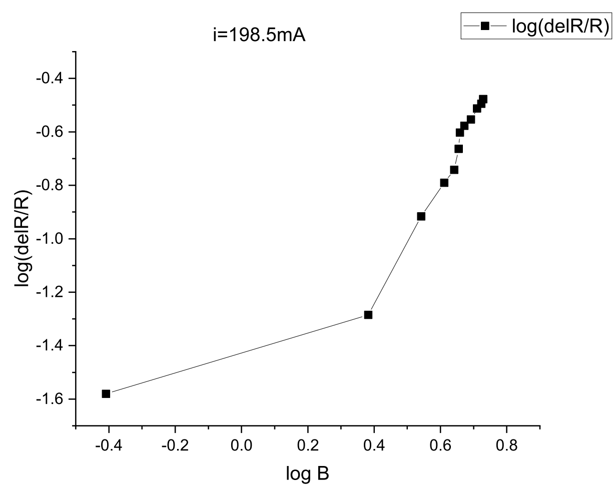

FIG. 2: $log(\Delta R/R)$ vs log(H)

from equation 2, we have
$R = \frac{V_h z}{IH}$

H(gauss)	Voltage(mv)	Resistance	deltaR/R
0	0.036	0.000183861	0
3330	0.037	0.000188968	0.026291892
4260	0.038	0.000194076	0.051915789
4670	0.041	0.000209397	0.121287805
4950	0.043	0.000219612	0.16215814
5120	0.044	0.000224719	0.1812
5380	0.046	0.000234934	0.2168
5800	0.048	0.000245148	0.249433333

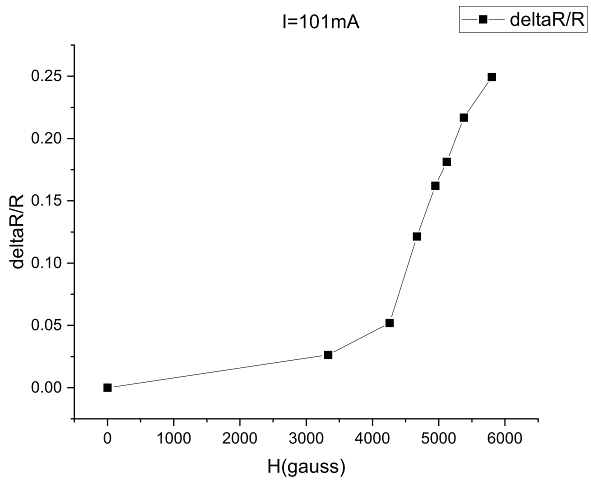

FIG. 3: $(\Delta R)/R$vs H

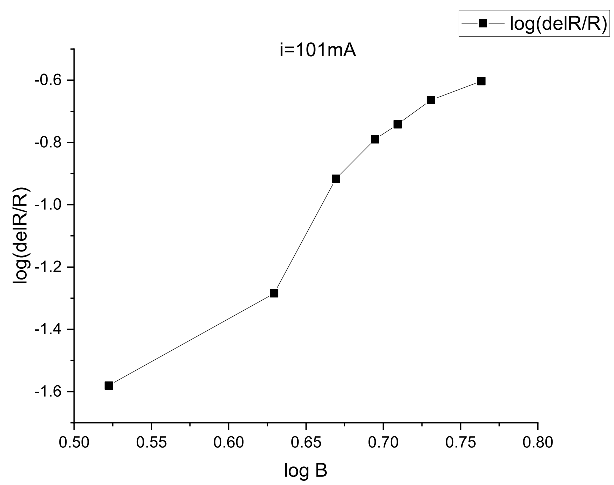

FIG. 4: $log(\Delta R/R)$ vs H

$R = \frac{slope * z}{I}$,
hall coefficient, R=-6.951 x $10^{-12} ohm - cm/Gauss$

H(gauss)	V(mV)
2390	-0.061
2540	-0.062
3160	-0.063
3480	-0.064
4200	-0.065
4500	-0.066
4780	-0.067
5200	-0.068
5180	-0.069

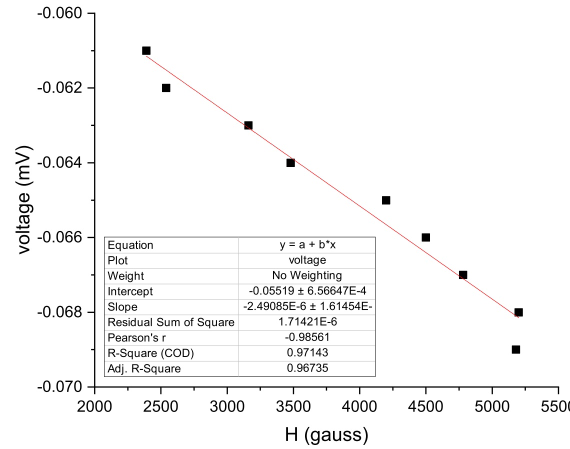

FIG. 5: hall voltage vs H

1. *Error analysis*

we have, from equation 2,
$(\frac{\Delta R}{R})^2 = (\frac{\Delta slope}{slope})^2 + (\frac{\Delta I}{I})^2$
as z is error is not mentioned. thus
ΔR=+-0.45 x $10^{-12} ohm - cm/Gauss$

C. Data analysis

We see that the magneto-resistance value increases with an increase in a magnetic field. The change is slow at low magnetic field intensity but increases as intensity increases. The reason could be due to an increase in Lorentz force on charge particles. we see that the change in resistance for Bismuth is 35 percent(i=198.5mA) and 25 percent(i=101mA) at the high magnetic field. The change in magneto-resistance decreases as the current operating decreases as the number of charge carrier decreases. Further, we can see that the curve deviates from the expected curve shape at the low operating current and saturates at high temperatures due to limited charge carriers.
In the Hall coefficient, we see that the error in the Hall coefficient value is about 6 percent. The following deviation in data points could be due to increased temperature, as equipment heats up due to continuous use and fluctu-

ation of room temperature. Another factor can be due to the residual magnetic field in coils at zero current(3 Gauss) and fluctuation of operating current. As we have $R_h = 1/ne$ thus charge density is high as expected in metals.