重庆大学-辛辛那提大学联合学院

学生实验报告

CQU-UC Joint Co-op Institute (JCI)
Student Experiment Report

实验课程名称 Experiment Course Name College Physics Experiment II

开课实验室（学院）Laboratory (School) CQU-UC

学院 School JCI 年级专业班 Student Group 2018 ME01

学生姓名 Student Name 易弘睿 学号 Student Number 20186103

学年 Academic Year 2019——2020 学期 Semester Spring

成绩 Grade	
教师签名 Signature of Instructor	

批改说明 Marking instructions:

指导老师请用红色水笔批改，在扣分处标明所扣分数并给出相应理由，在封面的平时成绩处注明成绩。

Supervisors should mark the report with a **red ink pen**. Please write down **the points deducted** for each section when errors arise and specify the corresponding reasons. Please write down **the total grade** in the table on the cover page.

重庆大学-辛辛那提大学联合学院________________________________实验报告

JCI ____Experiment Report

学院 School____Chongqing University______年级专业班 Student Group_________2018ME01_______
姓名 Name______________易弘睿______________ 学号 Student Number_______20186103_______
开课学院、实验室 Academic School/ Laboratory____________________CQU-UC____________________
实验时间 Date of Experiment________2020_________年 Year_____5_____月 Month____7____日 Day
报告时间 Date of Report_______2020________年 Year____5____月 Month_____10_____日 Day

课程名称 Course Name	College Physics Experiment II	实验项目名称 Experiment Project	Magnetization Curve and Hysteresis Curve of Ferromagnet	实验项目类型 Type of experiment project				
				验证 Verification	演示 Presentation	综合 Comprehensive	设计 Design	其他 Others
指导老师 Supervisor	边立功	成绩 Grade		√				

实验目的 Description/Instruction:

1. To understand the basic principles of the oscilloscope to show the hysteresis curve;
2. To learn to measure and draw magnetization curve and magnetic hysteresis using oscilloscope.

原理和设计 Principle and Design:

1. The original magnetization curve, basic magnetization curve and magnetic hysteresis

Ferromagnetic materials(Iron, cobalt, nickel, and many of their alloys) have unique magnetization properties. Now take a piece of steel ring sample made of unmagnetized ferromagnetic material with coils tightly surrounded as an example, if the magnetization current running through coils gradually increases from zero, then the magnetic induction density B increases as the magnetic strength H increasing at the beginning of magnetization. When reaching a certain value H, B no longer increases with H increasing, that is, the material attains the saturated states, as the o-a period shown in Fig. 1. This curve is called the original magnetization curve. If H gradually decreases, then B decreases correspondingly, not drops along the a-O period, but along another curve a-b. The whole process that B changes with H is shown below:

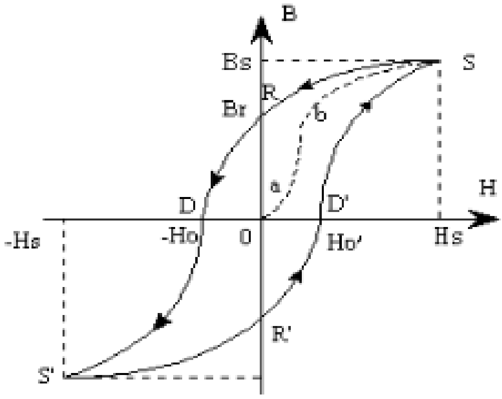

Figure 1 The Original Magnetization Curve

When H varies by the sequence O → Hm → O → -Hc → -Hm → O → Hc → Hm, correspondingly, B varies by the sequence O → Bm → Br → O → -Bm → -Br → O → Bm. Connect each point in the process introducing above, we can get a closed curve abcdefa. Because the magnetic induction density B always varies after the magnetic strength H, so this phenomenon is called magnetic hysteresis, and this curve is called the hysteresis curve. It can be concluded from Fig. 1 that:

The origin O in the figure shows that the ferromagnetic material is in a magnetically neutral state prior to magnetization, that is, B = H = O. When the magnetic field H increases from zero, the magnetic induction B slowly rises, as shown in the period o-a, As H grows rapidly, as shown by ab, the growth of B then tends slowly again, and when H increases to HS, B reaches the saturation BS, and the curve oabs is called the initial magnetization curve. Fig. 1 shows that when the magnetic field decreases gradually from HS to zero, the magnetic flux density B does not return to the "O" point along the initial magnetization curve but decreases along another new curve ab. Comparing the line segments o-a and a-b, it can be seen that H The decrease of B decreases accordingly, but the change of B lags behind the change of H, which is called hysteresis. The obvious characteristic of hysteresis is that when H = O, B is not zero, while retaining the remanence Br.

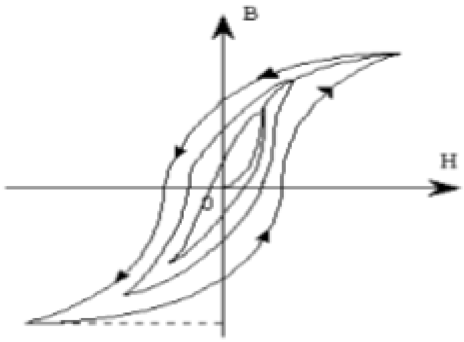

Figure 2 The Basic Magnetization Curve

When the magnetic field reverses from O to -Hc, the magnetic induction B disappears, indicating that to eliminate remanence, a reverse magnetic field must be applied. Hc is called the coercivity, and its size reflects the ability of the ferromagnetic material to maintain the remanence state , The line segment RD is called demagnetization curve.

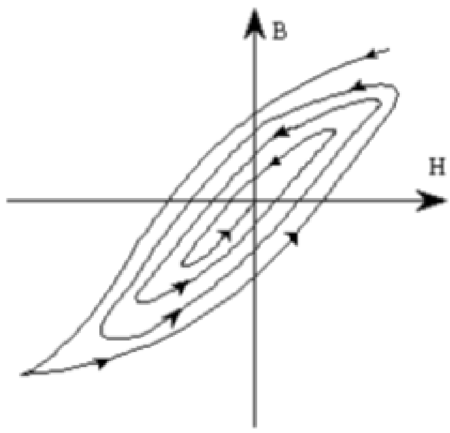

Figure 3 The Hysteresis Curve

Fig. 1 also shows that when the magnetic field changes in the order O → Hm → O → -Hc → -Hm → O → Hc → Hm, the corresponding magnetic induction B changes along the closed curve abc-acb, which is called the hysteresis loop line. Therefore, when the ferromagnetic material is in an alternating magnetic field (such as the core of a transformer), it will be repeatedly magnetized along the hysteresis loop → demagnetized → reversed magnetized → demagnetized backwards. In the process, extra energy is consumed and released as heat from the ferromagnetic material. This loss is called hysteresis loss and it can be shown that the hysteresis loss is proportional to the area enclosed by the hysteresis loop. It should be shown that when the ferromagnetic material with initial state H = B = O, a series of hysteresis loops whose area expands outwardly from small to large can be obtained when the intensity of the alternating magnetic field is sequentially magnetized from weak to strong, as shown in Fig. 2, these hysteresis loop vertices are called the basic magnetization curve of ferromagnetic material, which can be approximately determined by the permeability of H, because B and H non-linear, so the ferromagnetic material μ is not The constant changes with H. The relative permeability of ferromagnetic materials can be as high as thousands or even tens of thousands of this feature is one of the main reasons for its wide range of uses.

2. The principle and circuit of the oscilloscope to show hysteresis curve

In order to display the hysteresis loop of the oscilloscope, we input the voltage proportional to the sample magnetic field intensity H in the X-deflection plate of the oscilloscope, and the voltage proportional to the sample magnetic induction intensity B in the Y-deflection plate. The B-H curve of the sample can be obtained on the fluorescent screen.

As shown in Fig. 4, if the voltage $U_x = I_1R_1$, R_1 is connected to the X-axis input of the oscilloscope, due to the magnetization current:

$$I = HL/N_1$$

Then:

$$U = \frac{LR_1}{N_1} H$$

In order to obtain the voltage uy proportional to the instantaneous value of magnetic induction:

intensity B in the sample, an integral circuit composed of resistance R_2 and capacitance C is adopted, and the voltage at both ends of capacitance C is connected to the Y-axis input end of the oscilloscope. Because the alternating magnetic field H produces alternating magnetic induction intensity B in the sample, the induced electromotive force appears in the secondary coil. The magnitude of the induced electromotive force is as follows:

$$E_2 = \frac{d\varphi}{dt} = N_2 A \frac{dB}{dt}$$

In order to display the hysteresis loop faithfully, it is required that:

The time constant of integral circuit R_2C should be more than 100 times larger than $1/2\pi f$. In this way, Uc is negligible compared with I_2R_2, so the equation can be simplified as follows:

$$E_2 = I_2 R_2$$

2) When the condition (1) is satisfied, the amplitude of uc is very small. If it is directly added to the Y deflection board, the hysteresis loops of suitable size can not be displayed. For this reason, it is necessary to input the Y deflection board after increasing the amplitude of the Y axis amplifier. This requires that in the frequency range of the experimental magnetic field, the amplification coefficient of the amplifier must be stable, without causing large phase distortion and frequency distortion.

The voltage at both ends of the capacitor is expressed as:

$$U_c = \frac{Q}{C} = \frac{1}{C}\int I_2 dt = \frac{1}{CR}\int E_2 dt$$

Then we get:

$$U_c = \frac{N_2}{CR_2}\int \frac{dB}{dt} dt = \frac{N_2 A}{CR_2}\int_0^B dB = \frac{N_{2A}}{CR_2} B$$

3. Measure H and B at any points on the hysteresis curve

In order to get the B and H values of the points obtained by the hysteresis loop, coordinates x and y of the points need to be measured to calculate the voltage $U_x = nS_x \cdot x$ and $U_y = nS_y \cdot y$ added to the oscilloscope, where n is the attenuation number of the cable connecting the X input and Y input of the oscilloscope. In this experiment, S_x and S_y are respectively the sensitivity indicators of the X input and Y input of the oscilloscope.

Then we get:

$$H = \frac{10 N_1 S_x}{L R_1} x$$

$$B = \frac{10 C R_2 S_y}{A N_2} y$$

实验器材 List of instruments and materials:

DH4516 hysteresis loop tester, digital multimeter, oscilloscope.

实验步骤 Implementation:

1. Circuit Connection: Select Sample 1 Connect the circuit according to the circuit diagram given on the tester and set R1 = 2.5Ω and "U Select" to O position. UH and UB are connected to the oscilloscope "X input" and "Y input";
2. Sample demagnetization: Turn on the power of the tester and demagnetize the sample. Turn the "U select" knob clockwise to increase U from 0 to 3V, then turn the knob counterclockwise to decrease U from the maximum value to 0, Its purpose is to eliminate remanence, to ensure that the sample is in a magnetically neutral state;
3. Observe the hysteresis loop: Turn on the power of the oscilloscope so that the light spot is at the center of the coordinate grid, adjust the sensitivity of the x and y axes of the oscilloscope respectively to make

the hysteresis curve;

4. Observe the basic magnetization curve, demagnetize the sample according to step 2, starting from U = 0, increase the excitation voltage step by step, and get a set of hysteresis loops with a small area and a large area on the display screen. The connection of these hysteresis loop vertices is the basic magnetization curve of the sample. With long persistence oscilloscope, the trace of the curve can be observed;

5. Plotting H-B curve.

实验结果和数据处理 Results and Data processing:

Table 1 Data to Draw the Hysteresis Loop

Measurement	Hm	Bm	Hc	Br	-Hc	-Br	-Hm	-Bm
Oscilloscope corresponding lattice number (small lattice)	12	10	6	7.2	-6	-7.2	-12	-10

Table 2 Data to Draw the Magnetization Curve

Voltage	10	20	30	40	50	60	70	80	90	100
Ux	2.5	3.2	3.5	4	5	6.5	8.8	11	14	17.5
Uy	1.2	2.5	3.8	5	6.4	7.5	9	10	11	11.5
Hm	22.07627639	28.25763	30.90679	35.32204	44.15255	57.39832	77.70849	97.13562	123.6271	154.5339
Bm	0.017996476	0.037493	0.056989	0.074985	0.095981	0.112478	0.134974	0.149971	0.164968	0.172466
Relative permeability	648.7117867	1055.846	1467.324	1689.354	1729.898	1559.403	1382.198	1228.621	1061.879	888.1173

Table 3 Calibrate magnetic field intensity H

Current	0.02	0.04	0.06	0.08	0.1	0.12
My	8.5	16.2	24.5	32.2	40.5	48.2
H0	8.472445702	8.890838	8.81826	8.946061	8.890838	8.964621

Table 4 Calibrate magnetic field intensity B

Current	0.05	0.1	0.15	0.2	0.25	0.3
My	6.8	14	20	26.4	32.4	40
B0	0.014772729	0.014351	0.015068	0.01522	0.015502	0.015068

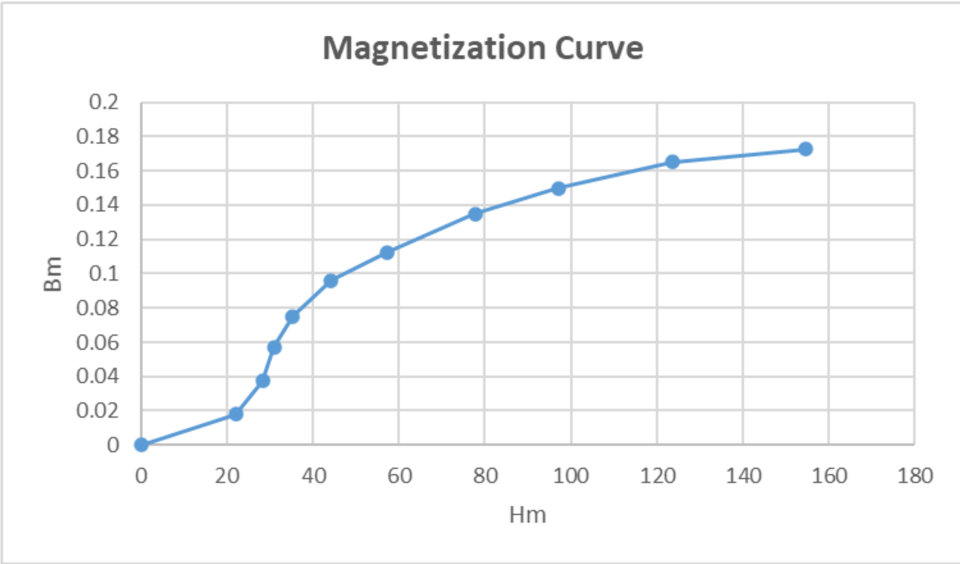

Figure 4 Magnetization Curve

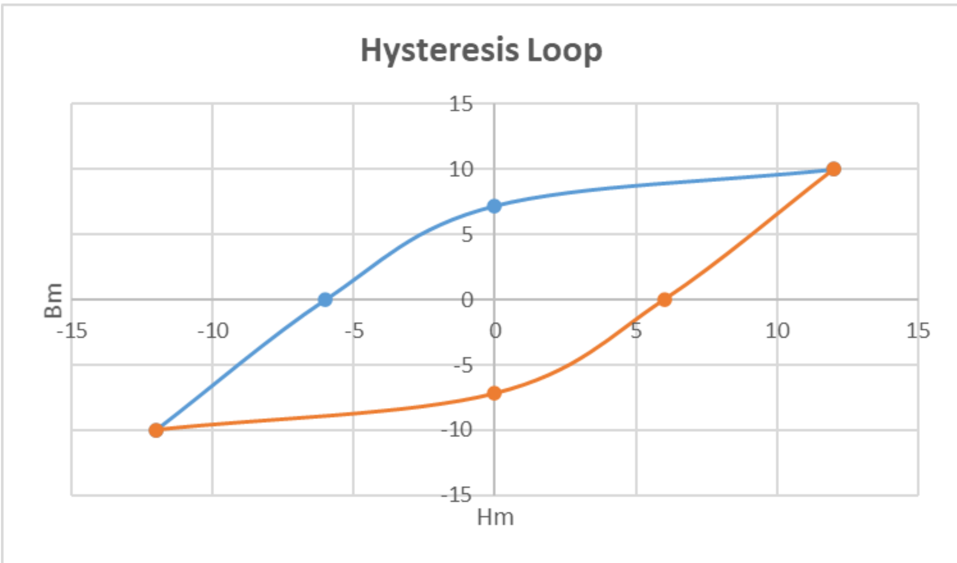

Figure 5 Hysteresis Loop

The data use in calculate:

N1=600, I=47.123cm, N2=75, S=1.3273cm^2 M=0.01H

实验讨论 Discussions:

1. Errors:

   Errors may come from two parts: measurement errors and instruments errors.

①The biggest error of this experiment is that, as I initially estimated the two decimal places in the reading, and later corrected by the teacher. But at the time there was not enough time to re-run the experiment, so I rounded up the original data and got the current data, resulting in some errors (because some data intervals are too small, there is duplication after rounding).

②Another problem is that the x, y coordinates are read by the human eye, not the exact data given by the instrument, so there is a reading error.

③Other errors may come from instruments, such as aging and abrasion.

2. Discussion:

(1) If the cable connecting the oscilloscope input and Y input is attenuated to "10", then calculate H and B. What is the difference between the formulas? A: According to the above equation, B and H are

proportional to y, So they will be also 10 times than before.

(2) From the basic magnetization curve, according to the relationship $B=\mu H$, $\mu=\mu_0\mu_r$, $\mu_0=4\pi*10^{-7}$,Calculating the maximum relative permeability of the ferromagnetic material

A: $\mu_r=1.271*10^3$.

物理实验 原始实验数据记录

Experiment Data

姓名 Name______易弘睿______学号 Student Number________20186103________实验时间_2020.5.7_
实验名称 Name of experiment: Magnetization Curve and Hysteresis Curve of Ferromagnet

仪器名称	量程	最小量	估读误差	仪器误差	零位误差
Analog oscilloscope x axis(div)	0~10	0.2	0.1	0.1	
Analog oscilloscope y axis(div)	0~8	0.2	0.1	0.1	
Hysteresis loop tester	0~222	0.1	0.1	0.1	
Ferromagnetic material to be measured					

实验数据 Experiment Data （表格自拟）

测饱和磁滞回线

80v的电流（A）= 0.59

使用前请先将示波器校准，并令光点位于坐标网格中心；分别调节示波器CH1增益为"50mV"，CH2增益为"0.1V"，并调节电源电压V=80V。记录饱和磁滞回线的Hm、Bm、剩磁Br、矫顽力Hc：

测量量	Hm	Bm	Hc	Br	-Hc	-Br
示波器对应格数(小格)	12.0	10.0	6.0	7.2	-6.0	-7.2

测量基本磁化曲线

示波器CH1和CH2的增益均保持不变；调节电源电压，使磁化电流从零逐渐增大。观察并记录对应的磁滞回线顶点坐标值Bm和Hm：

电压	10	20	30	40	50	60
Ux(小格)	2.5	3.2	3.5	4.0	5.0	6.5
Uy(小格)	1.2	2.5	3.8	5.0	6.4	7.5
Hm(A/m)	22.0762763	28.25763378	30.90678694	35.32204222	44.15255278	57.39831861
Bm(T)	0.017996476	0.037492659	0.056988841	0.074985317	0.095981206	0.112477976
相对磁导率大小μr	648.7117867	1055.846007	1467.32428	1689.353611	1729.898098	1559.403334

以μr-Hm曲线确定：初始磁导率

相对磁导率的初始化μr0= 648.71178

以μr-Hm曲线确定：最大幅值磁导率

相对磁导率的最大幅值μrm= 467.32428

标定磁场强度H

示波器CH1和CH2的增益档位保持不变；调节电源电压，使线路中的电流值逐渐增大，并记录对应的示波器格数(Mx为水平线总长主度)：

电流值(A)	0.02	0.04	0.06	0.08	0.10
Mx(小格)	8.5	16.2	24.5	32.2	40.5
位电压值表示的磁场强H0(A/m)	8.47	8.89	8.81	8.89	8.96

H0=(2*N1*I0*√2)/(l*Mx)，单位（A/m） 其中，待测样品主线圈匝数N1=600,样品的平均磁路l=47.123厘米

50mv档位每小格对应的磁场强度

50mv的H0(A/m)= 8.83

标定磁感应强度B

示波器CH1和CH2的增益档位保持不变；调节电源电压，使线路中的电流值逐渐增大，并记录对应的示波器格数(My为垂直线总长主度)：

电流值(A)	0.05	0.10	0.15	0.20	0.2
My(小格)	6.8	14	20	26.4	32.
示波器单位电压值表示的磁场强B0(T)	).014772729	).014350651	).015220387	).015220387	).01550

B0=(2*M*I0*√2)/(N2*S*My)，单位（T） 其中，待测样品副线圈匝数N2=75,样品的截面积S=1.3273平方厘米,标准互感器互感系数M=0.01H

0.1v档位每小格对应的磁感应强度

0.1v的B0（T） = 0.015

指导教师：边立功