PC3193 Summary: Zeeman Effect

Muhammad Shairil Danil Bin Sidin

A0182458W

1 Objective

In this experiment, we sought to determine the distance between two adjacent interference when there is no magnetic flux density, B, distance between two adjacent interference when there is no magnetic flux density for varying B from 6.0mT to 20.0mT as well as the relationship between the magnetic flux density against the current flowing through the coils.

Our experimental value for Δ s to be 0.214 $\pm$ 0.012mm. We were also able to get an experimental value for the $\frac{e}{m}$ ratio to be 2.592 $\pm$ 0.032 E11 Ckg^{-1}. Compared to the theoretical value of 1.758820 E11 Ckg^{-1}, we obtained a percentage of 47.4%.

2 Introduction

The spectral lines of a light source in a magnetic field can undergo splitting. This splitting is known as the Zeeman Effect. For a cadmium red line, it is split into two outer σ and one π component. The central line, which corresponds to the spectral line of the light source (in the absence of a magnetic field) is polarized in the direction of the magnetic field while the outer lines are polarized perpendicular to it. The two split lines are circularly polarized against each other.

The splitting occurs due to an additional energy shift resulting from the interaction between the electronic magnetic moment with the magnetic field. A visible displacement of the spectral lines can be observed. The two σ components are shifted to a frequency v $+\Delta v$ and v $-\Delta v$, where v is the frequency of the spectral line. The equation below can be used to calculate the distance of one of the split lines from the original position of the interference lines, ds in a varying magnetic field, B:

$$ds = \frac{B}{4\pi c} \cdot \frac{e \cdot \Delta s}{m} \cdot \frac{2d(n^2-1)}{\sqrt{n^2-1}} \tag{1}$$

, where c is the speed of light = $3.0E8$ ms^{-1}, $\frac{e}{m}$ is the charge mass ratio of the electron = 1.758820 E11 Ckg^{-1}, n is the refractive index of the Lunmer-Gehrcke quartz glass = 1.4567, d is the thickness of the Lunmer-Gehrcke plate = 4.04mm and Δ s is the distance between two adjacent interference lines when there is no magnetic field present.

To observe this spectral lines, a cadmium lamp placed in a magnetic field produced by two adjacent coils produces spectral lines that are displaced upon the Lummer-Gehrcke plate. A telescope can be used to observe this lines and a polarizer inserted betwen the plate and telescope allows one to determine the sense of polarization of the Zeeman components.

The magnetic flux density was measured with a Teslamter of resolution 0.1mT and 1mT. The coil current was determined using METRAmax 4 ammeter 20 A DC with a resolution of 0.1A. Lastly, the seperation distance between the spectral lines were measured with a spectroscope of of 0.001mm resolution.

3 Experimental Results

Firstly, we were able to obtain a strong linear relationship between the magnetic flux density, B (mT), against Coil Current, I (A). The strong R^2 value = 0.995 further demonstrates this. This linear relationship is expected due to the Solenoid equation:

$$B = \mu_0 \cdot \mu_r \cdot \frac{n}{l} \cdot I \tag{2}$$

, where μ_0 is the magnetic constant, μ_r is the relative permeability, n is the number of turns in the coil and l is the length of the solenoid. Since these 4 factors are a constant, and under linearization:

$$Y = mX + C \tag{3}$$

, where $Y = B$, $m = \frac{\mu_0 \cdot \mu_r \cdot n}{l}$ is a constant, $X = I$ and C = 0. Thus, our graph fits with the mathematical prediction.

Meanwhile, it can be seen that our experimental values are much higher than what is expected. Since the percentage discrepancy between our experimental and theoretical $\frac{e}{m}$ ratio is 47.4% and therefore, much larger than 5.0%, our experimental values do not agree with the theoretical one. However, this could be due to the reason that it was difficult to accurately determine where the spectral lines are.

While they are relatively distinct, the spectral lines were still blurry and it gets even harder to align the crosshair with the spectral lines when the lens gets foggy due to condensation. Therefore, despite our best effort to get an accurate measurement, there were an uncontrollable uncertainty that was added to our readings. There was an overcompensation of this uncertainty that contributed to the larger readings than expected.

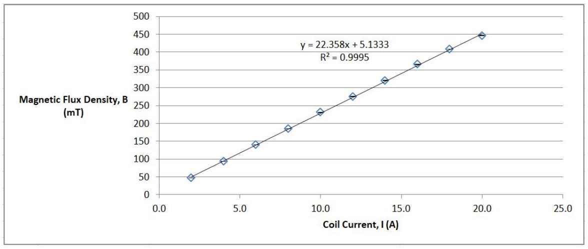

Figure 1: Graph of Coil Current, I (A), against magnetic flux density, B (mT)

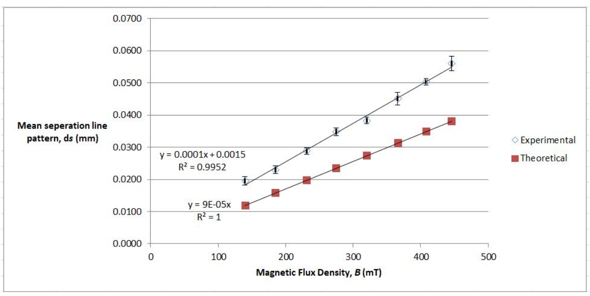

Figure 2: Graph of mean seperation line pattern, ds (mm) against magnetic flux density, B (mT) for both theoretical and experimental results

4 Conclusion

In this experiment, we sought to determine the distance between two adjacent interference when there is no magnetic flux density, B, distance between two adjacent interference when there is no magnetic flux density for varying B from 6.0mT to 20.0mT as well as the relationship between the magnetic flux density against the current flowing through the coils.

Our experimental value for Δ s to be 0.214 $\pm$ 0.012mm. We were also able to get an experimental value for the $\frac{e}{m}$ ratio to be 2.592 $\pm$ 0.032 E11 Ckg^{-1}. Compared to the theoretical value of 1.758820 E11 Ckg^{-1}, we obtained a percentage of 47.4%. Since this is more than 10%, our experimental results do not agree with the theoretical results. However, this was mainly due to overcompensation of the blurry spectral lines which causes our results to be alrger than expected. Despite so, the high R^2 value of 0.9995 and 0.9952 shows the strong linear relation for magnetic flux density, B (mT), against coil current, I (A), as well as mean seperation line distance, ds (mm) against magnetic flux density, B (mT).