# MAGNETIC OSCILLATOR AND TORQUE EXPERIMENT

Determining earth's magnetic field

Studio # 3
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# What was our experiment all about ?

Objective: The crux of our main experiment was to find earths magnetic field strength. "***B***".

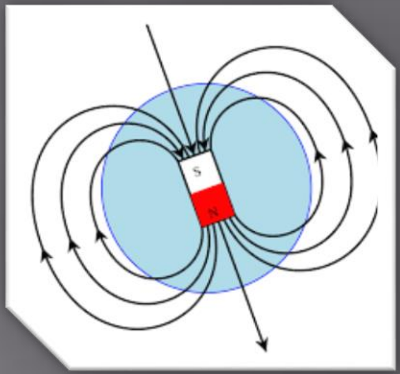
Now the question is how ?

**A pair of magnets suspended on a string oscillate due to the magnetic field of the earth**

**This is analogous to the behavior of the compass needle.**

We can time these Oscillations …


… and use them to calculate earth’s Magnetic Field Strength.



# Why magnets oscillate?

When suspended magnets from equilibrium position are displaced …

↓

… they experience restoring torque due to earth's magnetic field

↓

This torque causes the Magnets to oscillate about vertical axis

Frequency of these oscillations is directly proportional to the square root of product of earths magnetic field and the Magnetic moment of the magnet itself

In simple words, stronger the magnets, faster will be the oscillations.

# Backbone of the Experiment

$$P^2(N^2) = \frac{\pi^2 m}{\mu_1 B}\left(\tfrac{1}{3} b^2 N^2 + R^2\right).$$

Dependent Variable

Independent Variable

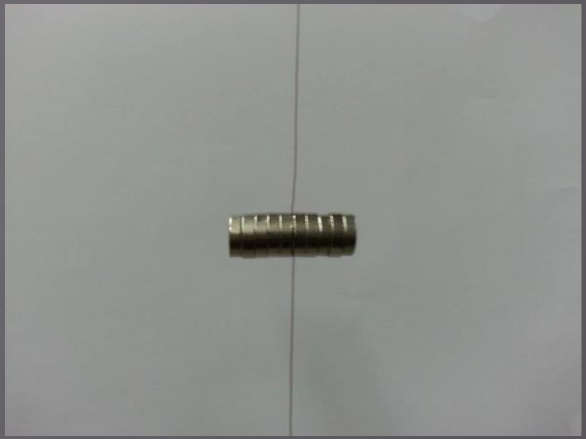
m= Average Mass of a magnet
h= Average Thickness of a magnet
μ=Average Magnetic Moment
B= Earth's Magnetic Field Strength
N= number of Magnets
$P(N^2)$= Time Period as a function of N

# Method

Set up the experiment as shown on the right.

Time 20 oscillations and calculate the Time Period

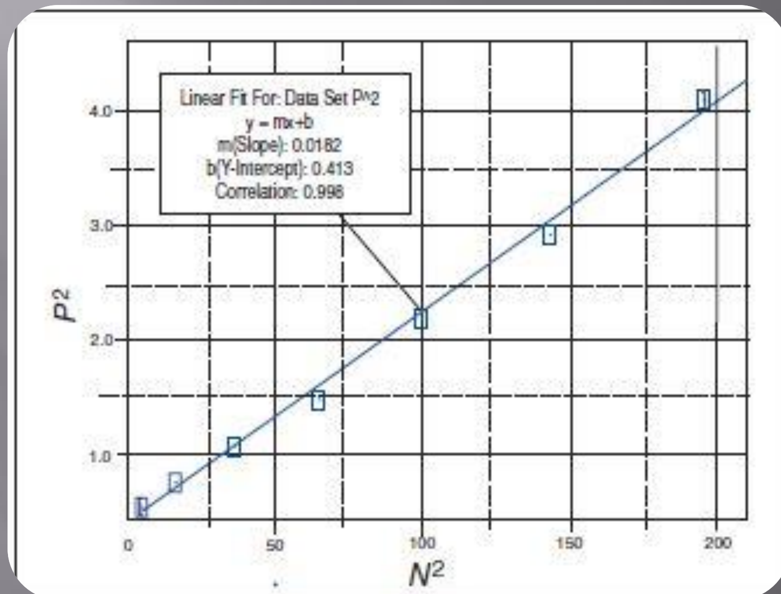
Vary the Number of Magnets and record the Time Period for different even values of N



Tabulate the Result as shown

| N | $N^2$ | T/s | $T^2$ / $s^2$ |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

Plot $T^2$ against $N^2$




$$Gradient = \frac{\pi^2 m h^2}{3\mu B}$$

Use this equation to calculate μB

# Calculating the Magnetic Moment


1. Using a Hall Sensor

2. Piston Experiment

# Using a Hall Sensor

Calculate Magnetic field '**B**' from the Hall Voltage measured at distance '**x**'

$$B = 320V_H - 800$$

$$B(x) \approx \frac{\mu_0 M}{2}\left(\frac{x + l/2}{\sqrt{(x + l/2)^2 + a^2}} - \frac{x - l/2}{\sqrt{(x - l/2)^2 + a^2}}\right),$$

$B(x) = \frac{1}{2}\mu_0 M f(x)$

$M = \mu / V$

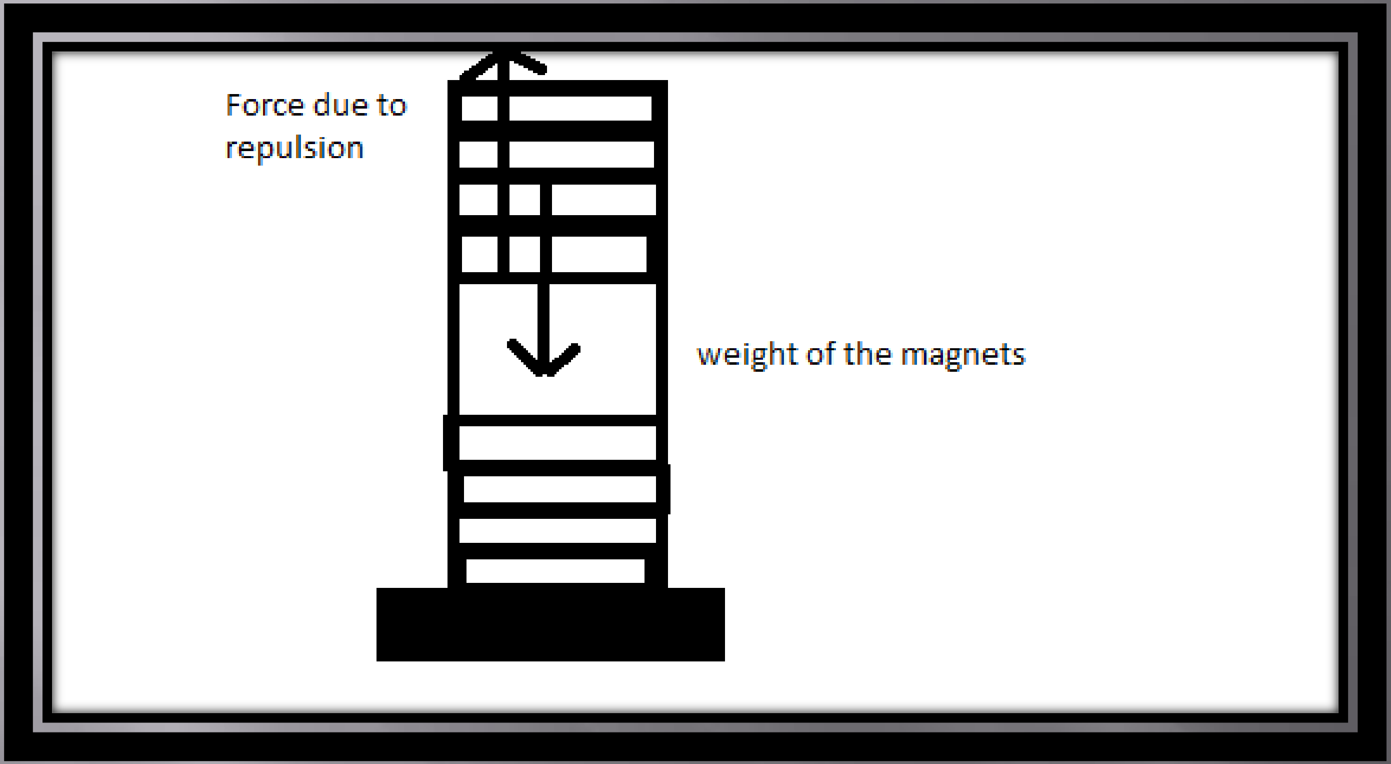
M=Magnetization
V=Average Volume of a magnet
l=Average Thickness of a magnet
a=Average Radius of a magnet
$V_H$ = Hall Voltage
μ = Magnetic moment

Plot B(x) against f(x)

# The Piston Experiment

This experiment uses the repulsion of the same poles of the magnets in order to calculate the magnetic moment of the magnets.

METHOD: Place four magnets at the bottom of the piston .Then place four more magnets on top of the previous ones such that the top four magnets repel the bottom ones. Measure the distance and calculate the magnetic moment.




$$\mu_1 = \sqrt{\frac{10^7 mg}{3} z^2}$$

The weight of the magnets is equal to the force due to repulsion. Incorporate the distance of separation to measure the magnetic moment.

Repeat the experiment …

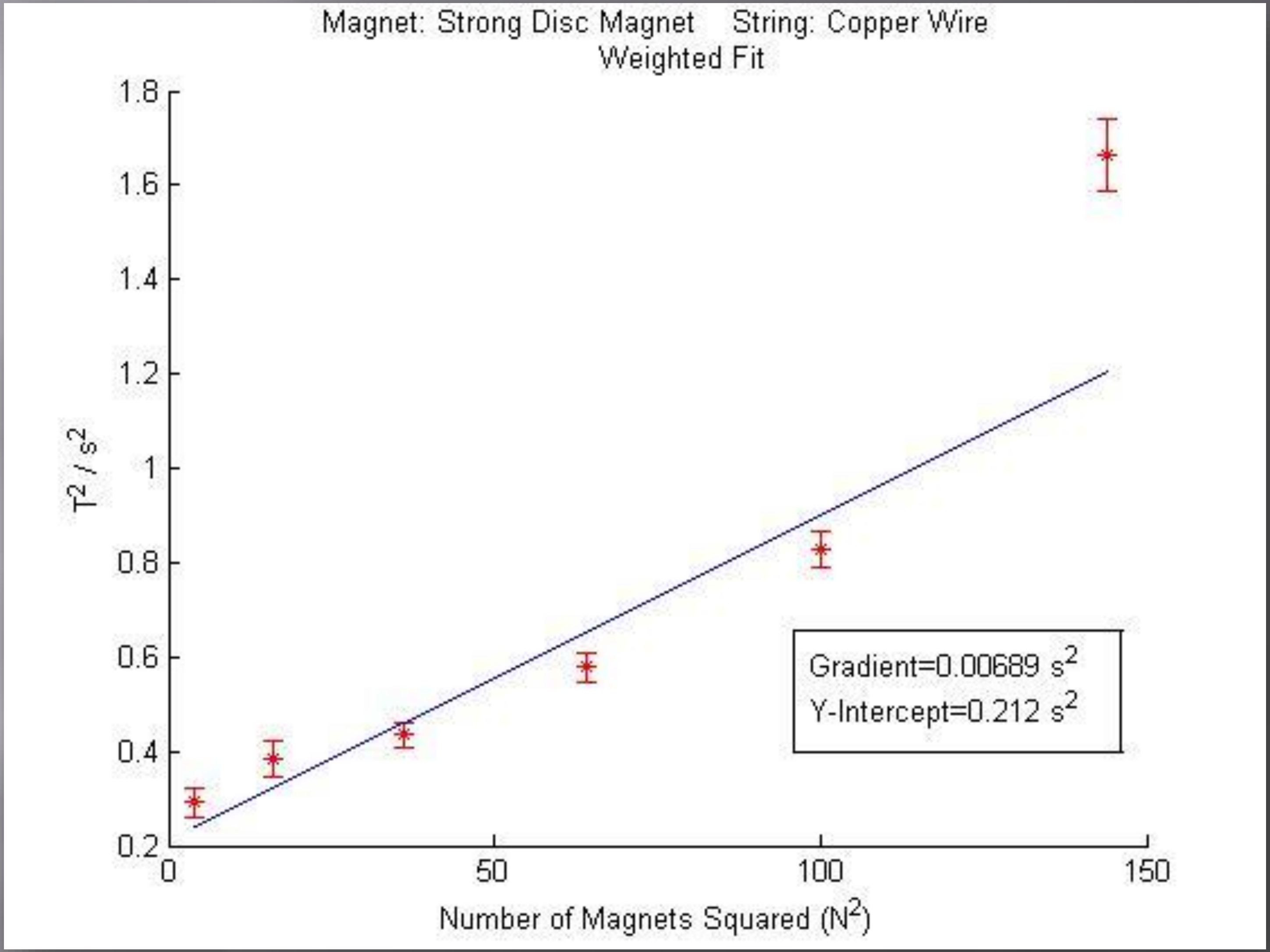
… for different types of magnets
(e.g. Small Disc Magnets and Long Cylindrical Magnets)

… and different types of strings
(e.g. Copper wire, Steel Wire, Thin Thread, Fat thread)

# Sample Results

Magnets used : Small Disc Magnets  String : Copper Wire

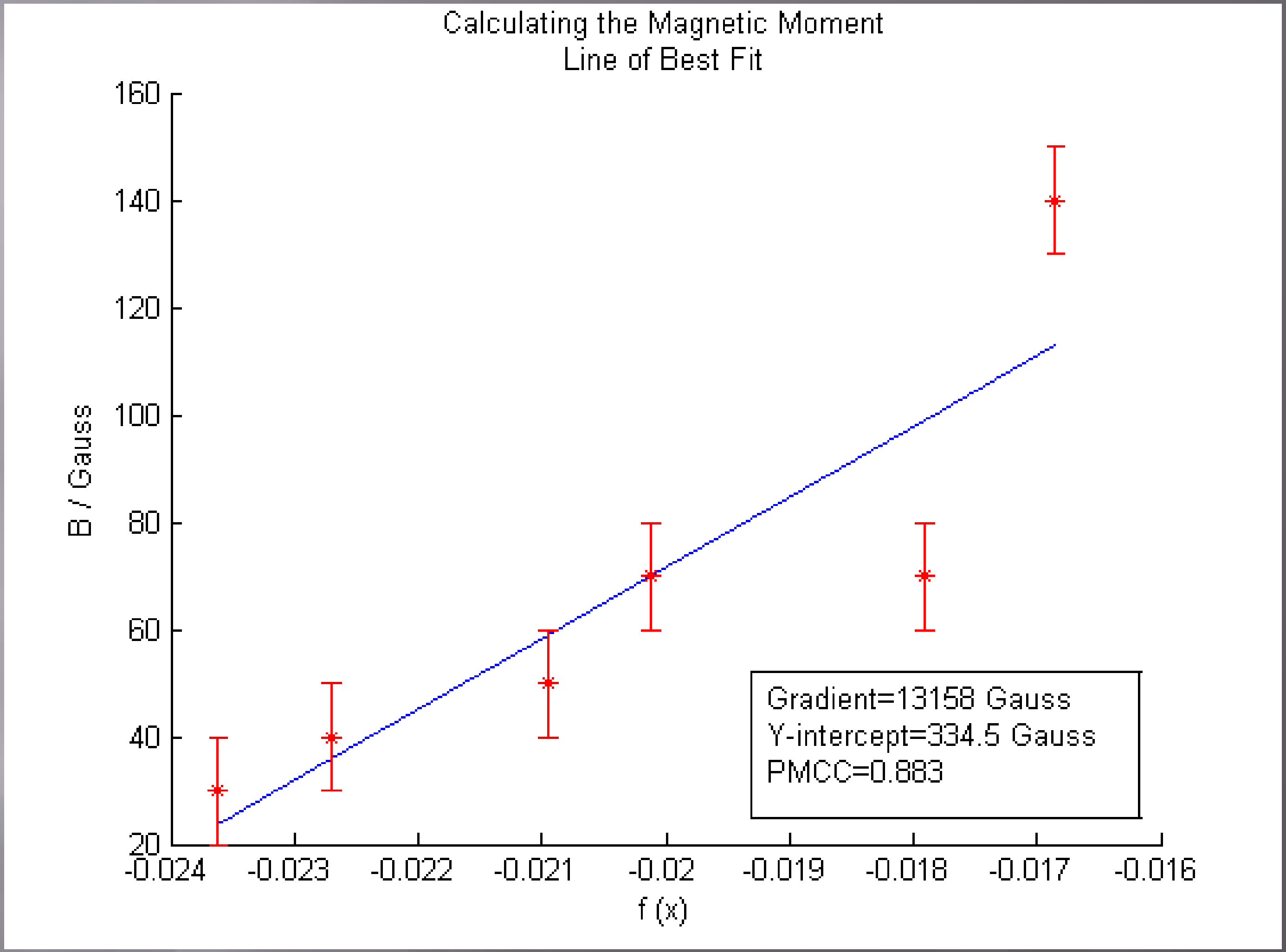
| N | $N^2$ | T / s | $T^2$ / $s^2$ |
|---|---|---|---|
| 2 | 4 | 0.54 ± 0.03 | 0.29 ± 0.03 |
| 4 | 16 | 0.62 ± 0.03 | 0.38 ± 0.04 |
| 6 | 36 | 0.66 ± 0.02 | 0.44 ± 0.03 |
| 8 | 64 | 0.76 ± 0.02 | 0.58 ± 0.03 |
| 10 | 100 | 0.91 ± 0.02 | 0.83 ± 0.04 |
| 12 | 144 | 1.29 ± 0.02 | 1.66 ± 0.08 |




h=0.0039 m
m=0.0052 kg
Gradient= 0.00689 $s^2$

$$Gradient = \frac{\pi^2 m h^2}{3\mu B}$$

The Calculated value of μB is $(3.8 \pm 0.5) \times 10^{-5}$ J

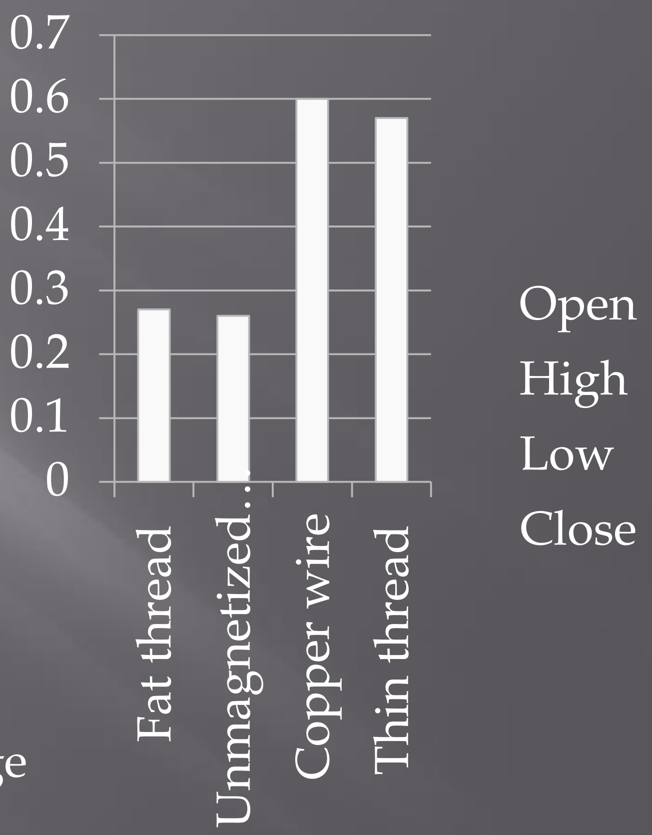



The Calculated of μ is $(1.5 \pm 0.2)\ Am^2$

Hence, the value of B is $(0.25 \pm 0.05)$ Gauss

# RESULTS

| **Wire and magnet** | **Values of μB** ***(Joules) in 10^-5*** | **B/Guass** |
|---|---|---|
| Fat thread | 2.79±0.05 | 0.27±0.05 |
| Unmagnetized wire | 2.64±0.04 | 0.26±0.04 |
| Copper wire | 4.40±0.07 | 0.60±0.01 |
| Thin thread | 4.17±0.05 | 0.57±0.01 |




The values of the experiment lie in the range between 0.6 and 0.2 ,which is in fact the range of the acceptable values of B.

# Precautions, Assumptions and Safety Measures

## Precautions

- Carry out the experiment in an isolated enviourment because surrounding magnetic fields (e.g mobile ,electrical wiring )may effect the final readings of the experiment.
- Keep away any electronic equipment
- Make sure that their are no twists or knots in the wire.
- The mass that is used to keep the wire taught should not be too heavy as it will also contribute to the inertia included in this experiment.

## Assumptions

- We are using an even sets of magnets in this experiment because when we use odd number of magnets the extra mass at one end itself produces a torsional effect.
- There is no other magnetic field that is influencing our experiment.
- The torsion of the wire/thread plays an insignificant role in this experiment.

## Safety measures

- Keep away people who have allergies from the metal that makes up the magnets.
- Since the magnets are strong ,they may attract sharp or dangerous objects towards the person that is performing the experiment. In order to avoid injury keep away any ferromagnetic material from the magnets.
- Keep apparatus (electronic balance ) away from sources of water.