ScienceCube

# Dipole

**Confirm that the magnetic field of a magnet composed of two or more magnets follows the ideal dipole magnetic field function and explain that it becomes a single dipole.**

## Fundamental Concept

Magnets are called dipoles because they usually have two poles, a south pole (S) and a north pole (N). If you split the two poles of a magnet, they do not separate into two isolated poles; instead, each piece still has two poles. Similarly, if you join two magnets, they still have two poles. Since monopole magnets do not exist, a dipole is the simplest form that can create a magnetic field. The magnetic field B created by an ideal dipole is measured as follows:

$$B_{axis} = \frac{\mu_0}{4\pi}\frac{2\mu}{d^3}$$

Where $\mu 0$ is the permeability constant with a value of $4\times10^{-7}$Tm/A. $d$ is the distance from the center of the dipole (unit: m), and $\mu$ is the magnetic moment $dl$. The magnetic moment $\mu$ is measured by the length of the magnet, similar to how the charge is measured by the length of the electric field line. This function shows an inverse cubic relationship with distance $d$.

In this experiment, let's verify whether a magnet made by joining two magnets also follows the dipole magnetic field function..

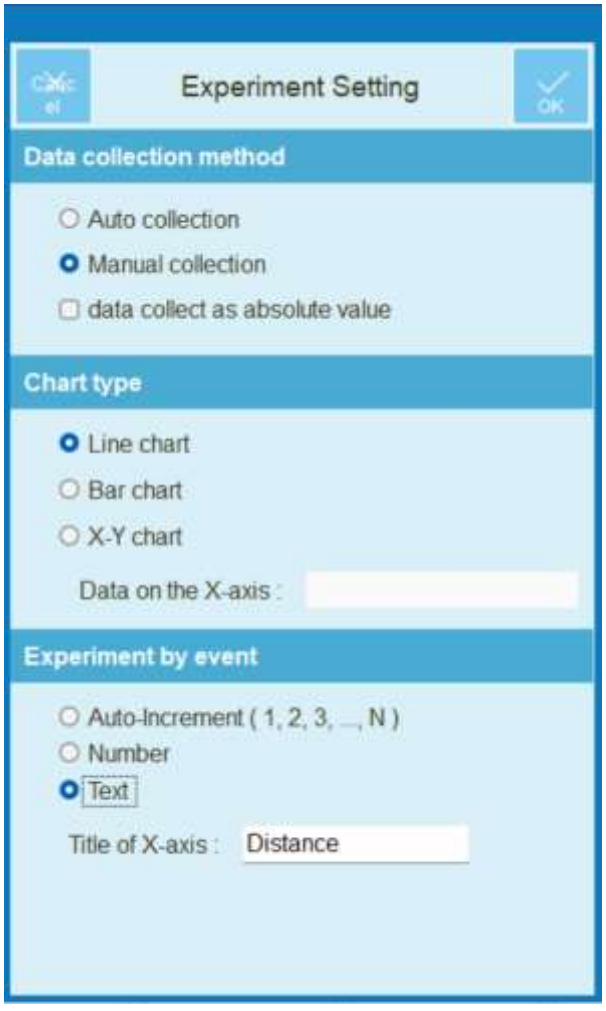
# Experiment

## Materials Needed

Interface, Science# program (smart device), Magnetic field sensor, Ruler, Two neodymium magnets, Business card, Transparent tape

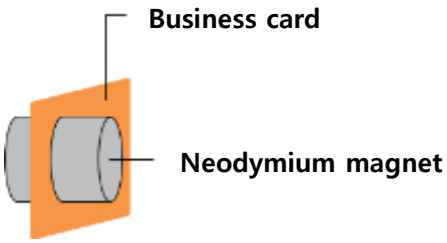
## Interface Setup

1. Run Science#.
2. Connect the magnetic field sensor to the interface.
3. Press the button to set up the experimental environment as shown below or press the button for automatic setup.



## Data Collection

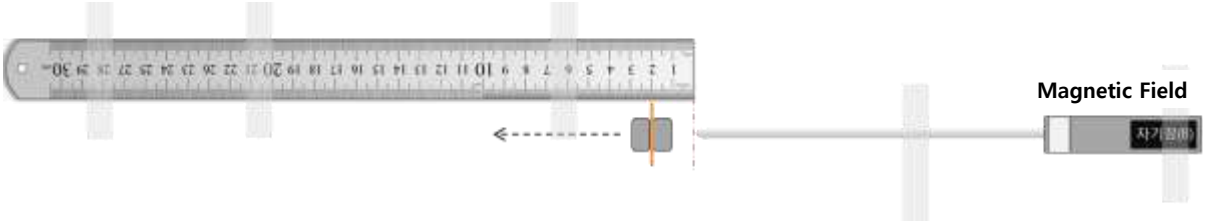
1. Place a business card between the two magnets and join them. (The reason for placing the business card is to easily identify the center of the dipole.)




2. Measure and record the magnetic field values of the front and back sides of the joined magnets as shown in the diagram below.


3. Fix the ruler and magnetic field sensor with tape as shown in the diagram. (Ensure the magnetic field sensor is horizontal to the ruler and the end of the sensor is at 0 cm.)


4. Press the button  to start data collection..
5. Stand the business card (dipole center) at a distance of 2 cm from the magnetic field sensor.




6. Press the button  and enter '2 cm'. (If the magnetic field value is negative, turn the magnet over to measure the opposite side.)
7. Measure the magnetic field values at increasing distances of 0.25 cm up to 5 cm between the magnetic field sensor and the business card.
8. Press the button  to stop data collection once the measurement is complete.

# Data Analysis

## Recording Data

1. Measure and record the magnetic field values and poles of the front and back sides of the joined magnets. (The magnetic field sensor shows the N pole as a positive value (+) and the S pole as a negative value (-).)

| | Front | Back |
|---|---|---|
| Magnetic Field (B) | | |
| Magnetic Pole (S/N) | | |

2. Measure and graph the magnetic field according to the distance from the center of the joined magnets to the magnetic field sensor.

## Data Application

1. When two magnets were joined, what poles did each side of the combined magnet show? Explain whether this is sufficient to prove that the joined magnets also form a single dipole.

2. The following is the magnetic field function of an ideal dipole:

$$B_{axis} = \frac{\mu_0}{4\pi}\frac{2\mu}{d^3} = (\frac{\mu_0 2\mu}{4\pi})\frac{1}{d^3}$$

If the joined magnets also follow the above function, then it can be considered that the combined magnet is also a dipole with both N and S poles. Analyze whether the dipole's magnetic field is proportional to the inverse cubic of the distance by transforming the graph in the analysis function.

**Analysis method:**

**[Data Analysis] - [Data Transformation (X-axis)] - [f(x)=Ax^n+B] - [Enter n=-3]**

3. What did you learn from the experiment and analysis? Explain with reasons.


Report
(For Teachers)
Report
(For Students)