Experimental Tasks: APhO 2022

Academic Committee: Chandan Ralekar, Siddhant Mukherjee, Siddharth Tiwary, Charudutt Kadolkar, Bipul Pal, Manoj Harbola, Mamatha Maddur, Praveen Pathak
Acknowledgement: Chinmay Haritas, Shirish Pathare

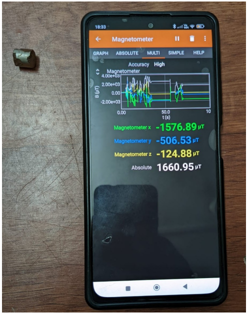
APhO 2022

EQ1: Magnetic Black box

Based on making use of various sensors available on a smartphone.

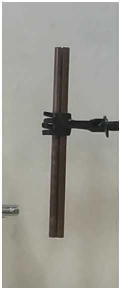
Motivation

Hall effect based magnetic sensor to detect the magnetic field.



Experiment

Blackbox (magnet in a conducting pipe)



To identify different sections of the pipe with the help of a smartphone.

Theoretical background

The axial magnetic field B_x of a point dipole (dipole moment M) at the distance x

$$B_x = \frac{\mu_0}{2\pi}\frac{M}{x^3}$$

When the magnet is moving with a constant non-relativistic velocity

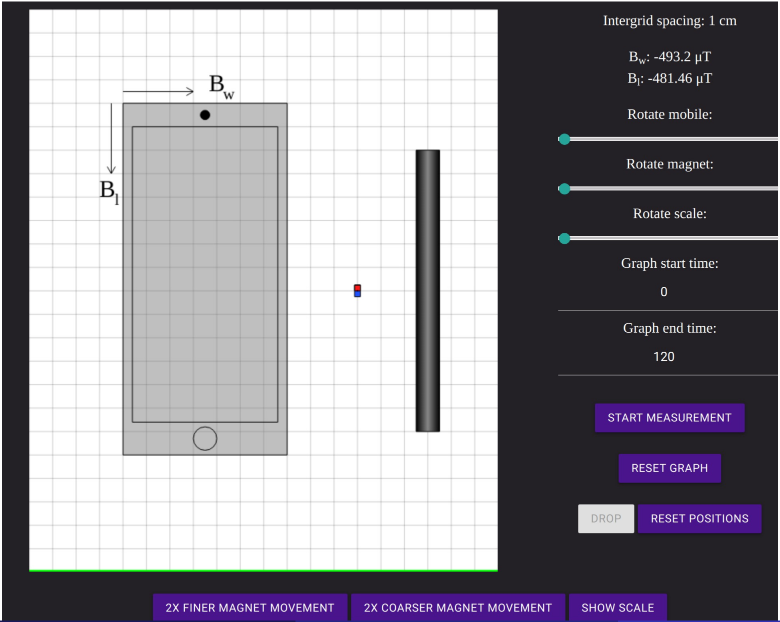
$$B_x(t) = \frac{\mu_0}{2\pi}\frac{M}{(vt)^3}$$

- $$\left(\frac{\mu_0 M}{2\pi B_x(t)}\right)^{1/3} = vt$$

Three parts of the experiment:

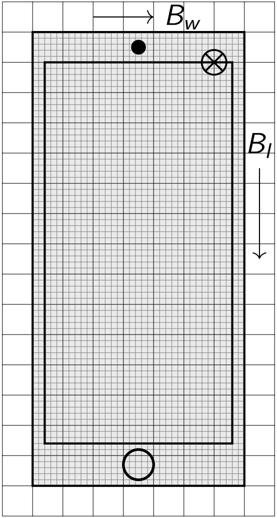
- Find the location of the magnetometer in the smartphone.
- Determine the dipole moment M.
- Determine v of the magnet.

Simulation

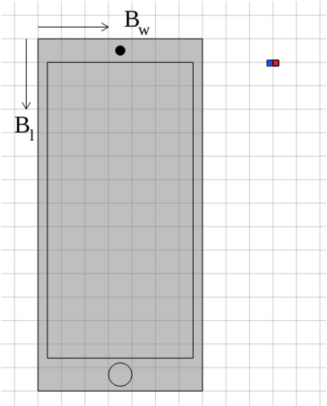


B_w
B_l
Intergrid spacing: 1 cm
B_w: -493.2 μT
B_l: -481.46 μT
Rotate mobile:
Rotate magnet:
Rotate scale:
Graph start time:
0
Graph end time:
120
START MEASUREMENT
RESET GRAPH
DROP
RESET POSITIONS
2X FINER MAGNET MOVEMENT
2X COARSER MAGNET MOVEMENT
SHOW SCALE

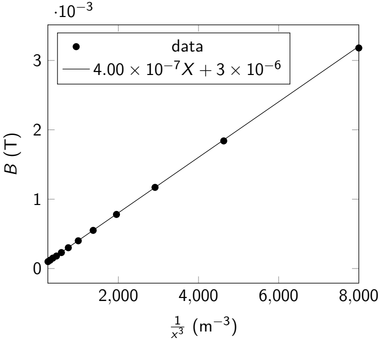
1. Find the location of the magnetometer



2. Dipole moment of the magnet

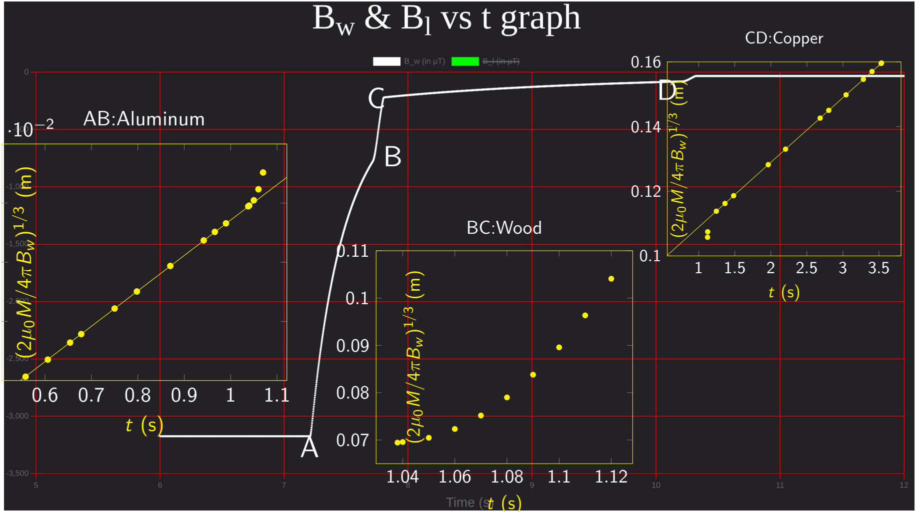


$$B_w = \frac{\mu_0}{2\pi}\frac{M}{x^3}$$



3. Identify sections of the pipe

When the magnet is dropped in a non magnetic conducting pipe such as aluminium or copper; $m\ddot{y} = mg - k\dot{y}$



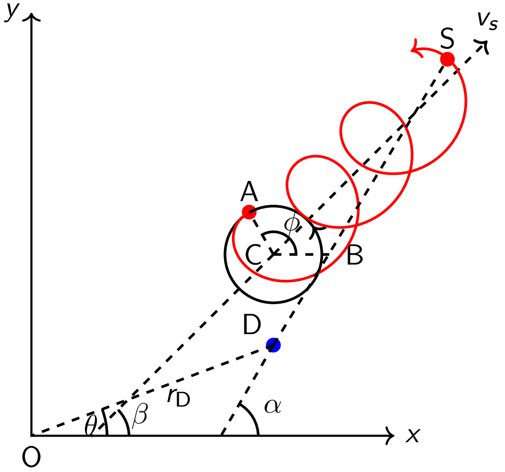
Length of each section

Identify the entry and exit time stamps in the data for each section and use the obtained velocities to calculate the section lengths.

EQ2: Accoustic Black box

Doppler effect in waves and an attempt to simulate acoustically the light waves emitted from the rotating planets.

Question



Sound source starts moving at A and emits frequency f_0. S is the position of the source at later time t.

You are given a detector D which you can place or move in the $x-y$ plane.

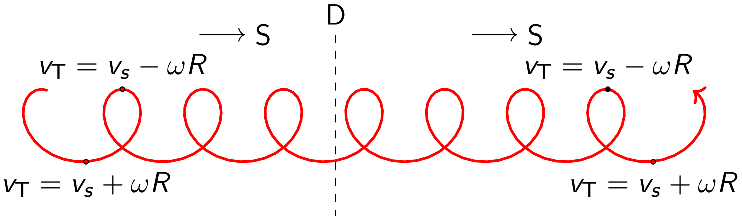
Find $f_0, \omega, R, v_s, \beta$, **coordinates of A and C.**

Detector's velocity: v_{D} Vector $\vec{DS}$: $\hat{n}$ Source's net velocity: v_{T}

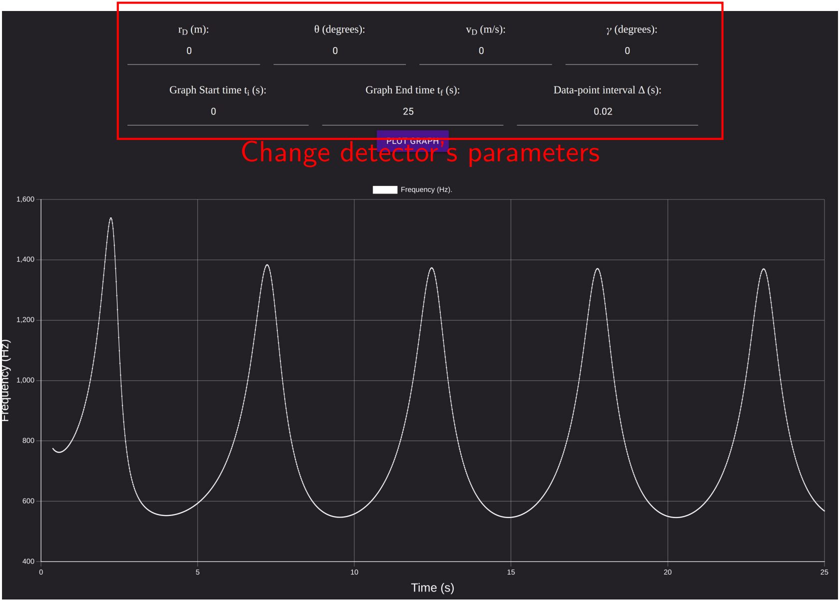
Frequency detected by the detector, when S is moving away (or approaching) from D

$$f(t') = f_0 \frac{c - \vec{v}_{\mathrm{D}} \cdot \hat{n}(t)}{c \pm \vec{v}_{\mathrm{T}} \cdot \hat{n}(t)}$$

At large distance (or time)



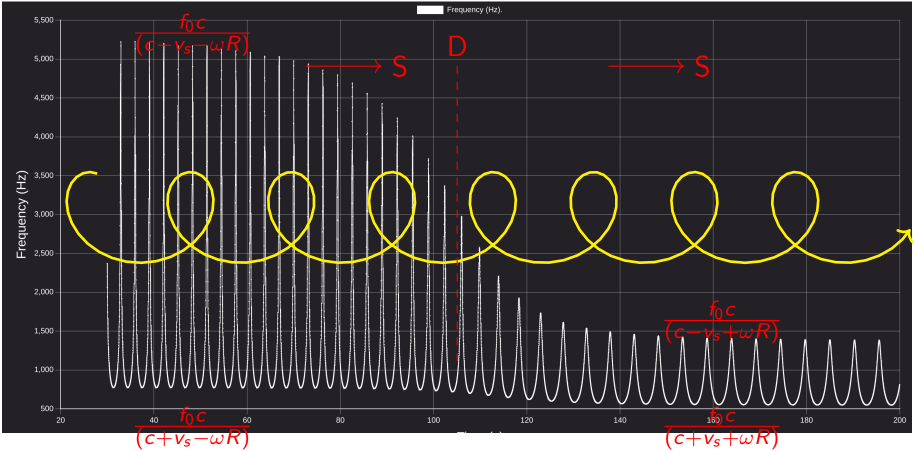
Simulation



rD (m):
0
θ (degrees):
0
vD (m/s):
0
γ (degrees):
0
Graph Start time ti (s):
0
Graph End time tf (s):
25
Data-point interval Δ (s):
0.02
PLOT GRAPH
Change detector's parameters
Frequency (Hz).
Frequency (Hz)
Time (s)

Asymptotic limit

Detector position $r_{\mathrm{D}} = 10000\,\mathrm{m}$, $\theta = 35^\circ$

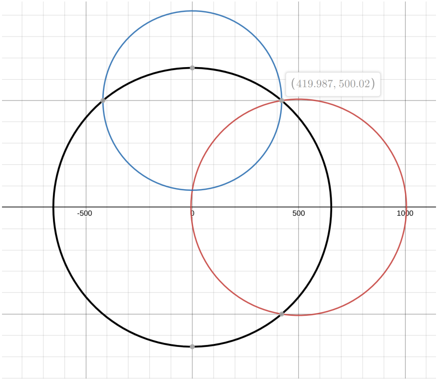


$$\frac{f_{\max}+f_{\min}}{f_{\max}-f_{\min}} = \frac{c-v_s}{\omega R} \qquad \Delta t = \frac{2\pi}{\omega}\left(1+\frac{v_s}{c}\right) \qquad \frac{f_{\max}+f_{\min}}{f_{\max}-f_{\min}} = \frac{c+v_s}{\omega R}$$

Above three equations yield f_0, ω, R, f_0 and v_s.

Source's initial coordinates - Triangulation

Detector Location (r_D, θ)	First signal received (s)
(500,0)	1.535
(0,500)	1.273
(0,0)	1.979



Summary

- How to setup an experiment.
- Observational and experimental skills, visualization, data interpretation and analytical skills.