# Magnetic arrows

For this experiment we need 2 magnetic arrows, a chronometer, and something to measure the amplitude of the oscillations.

# 1. One  Magnetic Arrow

First we are going to explain  the oscillations of a single magnetic arrow. A single magnetic arrow, is just a compass, which is very light, and has a low friction.
We may assume that the magnetic arrow is a current conductor with the transversal section’s area S and let I be the intensity of the current. So we have the magnetic moment of this conductor equal to the vectorial product of the area and intensity.

$m=I*S$

At the same time we have the torque equal to the vectorial product of the magnetic moment and the induction of an exterior magnetic field(this case the Earth magnetic field).

$\tau=m*B*\sin\varphi$

So the torque rotates the arrow to it’s initial position.

$-\tau=I*\alpha$ and $I*\alpha=-m*B*\sin\varphi$

And we’ll observe harmonical oscillations with a period

$T=2*\pi*[I/(m*B)]^{1/2}$

*Notes:*
*m-magnetic moment*
*I- inertia moment*
*S-section’s transversal area*
*τ-torque*
*B- the Earth’s magnetic field induction*
*α-angular acceleration*

# 2. Two Magnetic Arrows

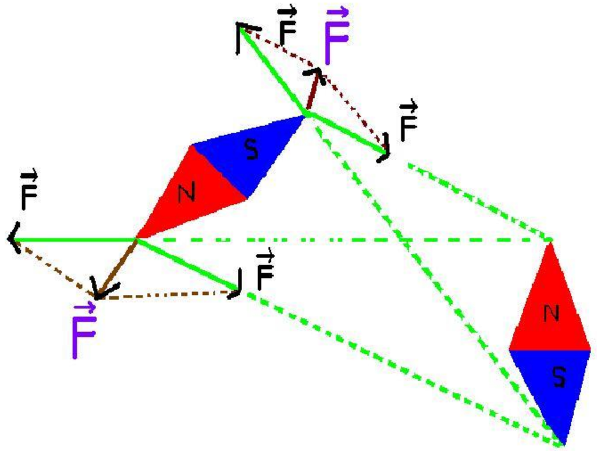
In this case for a higher precision we'll align the arrows according to the Earth's magnetic field. It's also important to mention that the distance  between the arrows has to be big enough to warn their contact and small enough to ensure their interaction.
We deflect one of the arrows by a small angle trying to maintain the equilibrium  of the second one. After that we release both arrows which will start oscillating. The first thing we observe is the asymmetrical character of the oscillations. For a detailed describing of this process we need a graphic of the dependence of the angle on time.

# Why are the arrows oscilating?

We may assume that the arrows, that form a stable system, are magnetic dipoles.Let's show how they are interacting. We have 2 types of forces acting on one pole af each arrow:

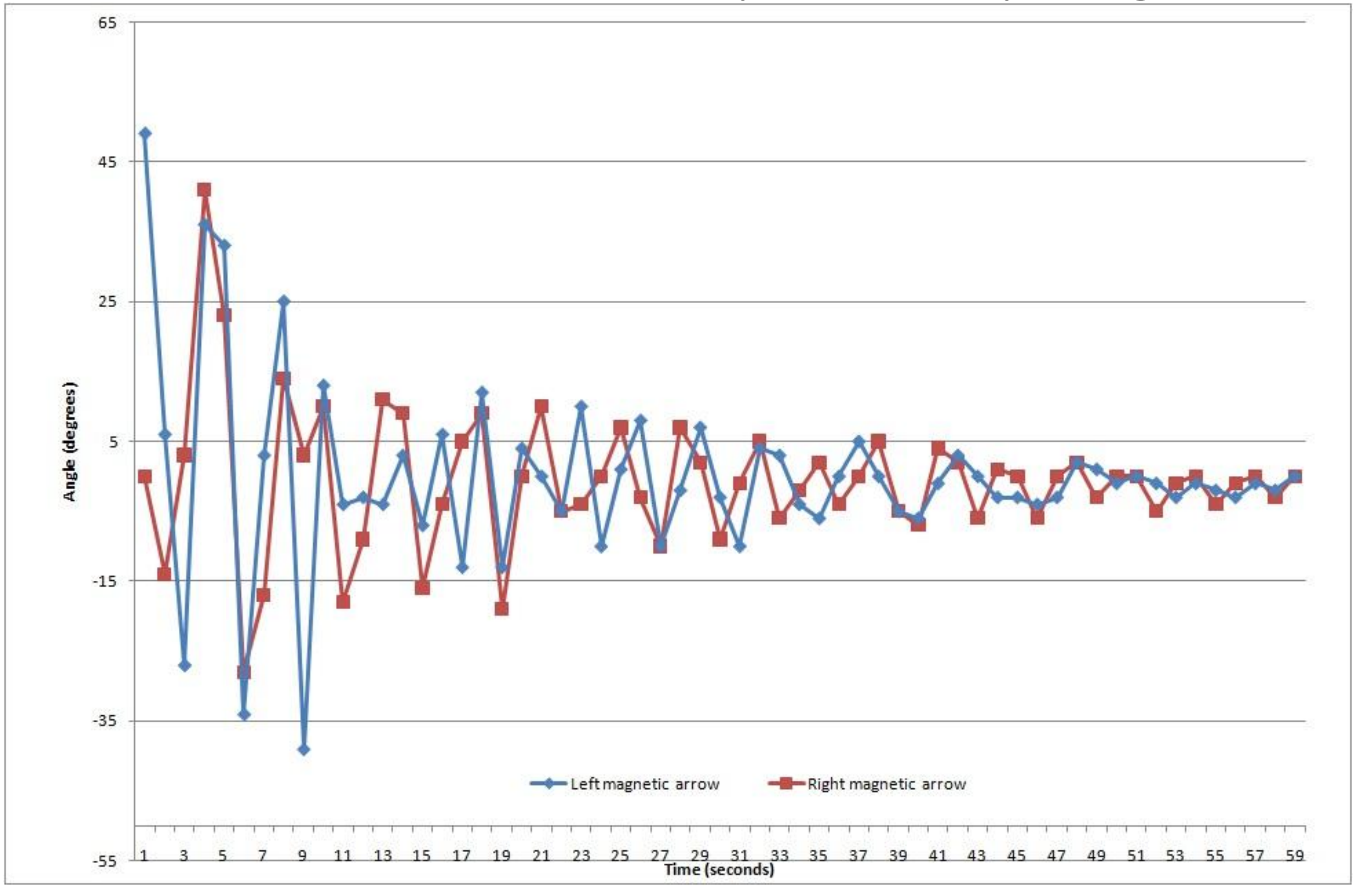
1) Atraction force between north of one arrow and south of another arow (the force moving the arrow toward each other)
2) Rejection force betwwen south of one arraw and south of another one or north od one arrow and north of another one (the force rotating the arrow in opposite directions). We  add the forces using the parallelogram's law and we obtain the resulting forces.

So the resulting force rotates the arrow. In this case the oscillations aren't harmonic and have different period. A complex oscillation is formed of one with big amplitude and one with small amplitude. Here's the graphic we made.



# The graphic of those oscillations

So the resulting force rotates the arrow. In this case the oscillations aren't harmonic and have a different period. A complex oscillation is formed of one with big amplitude and one with small amplitude. We observe the exponential character of the graphic ( f(t)= a*e^(-t) ), so the experimental data confirms the theory. But why aren't they oscillating forever? Because of the friction force in the axis. We may dimish it by using a lubricant, but it still remains.



Another reason of the cease of amortized coupled oscillations is the action of earth's magnetic field that tries to align the arrows according to earth's magnetic lines.
We obtained a graphic having an exponential character. Observing it we can confirm when one arrow has maximal deviation another arrow has minimal deviation. Why?
Because the energy of this system doesn't change in time, but the energy of every arrow changes and it compiles the kinetic and magnetic energies.
W=W(m)+W(k)
During the oscillation, at the maximal measure of the angle the arrow has maximal magnetic energy and the kinetic energy is zero. During this oscillation the arrow reaches the equilibrium position having maximal speed, that's why it continues to oscillate.
We observe errors (10%) big enough because it's complicated to measure small angles and considering the nature of this experiment it's a good result.
Initially we did an approximation , we considered the arrows to be magnetic dipoles and during the experiment, their interaction ( that we observe on the graphic) confirmed our hypothesis.

CONCLUSIONS

During this experiment we learnt that the oscillations of the arrow depends of the number of interracting arrows ( we have simmetrical amortized oscillations of one arrow and assimmetrical amortized oscillations of 2 arrows), we observed that for a higher precision we must arrange the arrows according to magnetic field's lines of earth. Our experiment confirmed the theory of oscilations and magnetical interraction, the exponential character of the graphic beeing a  good proof.