SPS Chapter at the Northern Virginia Community College in Annandale, VA was created in the Fall of 1990, 23 years ago. Its permanent advisor is Dr Walerian Majewski, who in 2001 was granted a title of an Outstanding SPS Chapter Advisor. Our chapter at least 6 times was named as an Outstanding SPS Chapter, and we have won 6 SPS Undergraduate Research Awards. In 2013 we won both SPS recognitions. Over years about 300 students were our members. Several of them are now PhD researchers in physics. Our current XXIIrd President in 2013-2014 academic year is Ian Bean, our officers: Agustin Mierez, Brendon Knopes, and Douglas Zabransky.

**Spring 2013 NVCC SPS Chapter**
Our grant was used to purchase Nd magnets, air-core inductors, motorized wheel, lab supplies, to cover the cost of printing posters and attending meetings.

Our research was presented at the following venues:

1. Three posters were presented by nine of our students at the Spring Meeting of the American Physical Society, March 2013, at the Baltimore Convention Center:

   - Inductional Effects in a Halbach Magnet Motion Above Distributed Inductance
   - Physical Models of a Toroidal Dipole
   - Experiments on Inductive Magnetic Levitation with a Circular Halbach Array

2. On April 6, 2013, seven program participants attended a meeting of the American Association of Physics Teachers, Chesapeake Section (CSAAPT), at J. Sargeant Reynolds Community College in Richmond. They presented the above topics as oral presentations.

3. SPS Zone 4 (Mid-Atlantic) Meeting: Towson University, Towson, MD, April 26-27
Six SPS members traveled to Towson University and made three PowerPoint presentations plus displayed and discussed three posters related to those topics.

**Spring 2013**

- **Three posters presented at the Spring Meeting of the American Physical Society, March 2013, by NVCC SPS Chapter members:**

![Poster presentation](image)

Austin Raymer, Chapter’s Co-President, reports:

Our trip to Baltimore dramatically changed my ideas about physics. Before, I believed that physics was best done with nothing but a sheet of paper, a pencil, my professor’s words, and a healthy imagination. What I saw, though, is that the field is more populated, more specialized, more dynamic, but, still, more collaborative than I had thought.

When our group first arrived at the conference, I was shocked to be around so many physicists. There were researchers gathered around every outlet in the convention center, grouped around the cell phone hot spots, and streaming in and out of the many lecture halls. Wherever there was space there were people, and all of them were talking physics. Every one of them was talking in their own excited but equally complex jargon. Somehow, though, there was networking going on. People were discussing experiments, exchanging business cards, and placing orders for equipment. We were just standing in line for registration, but scientific progress was happening all around us.

As time went on, though, people started to move on to the different sections. We got our first visitors then. The first of them were students. Some were curious about what their peers were working on, others; we found out, were just happy that there were projects they could understand. That was my first taste of sharing ideas with colleagues. Our conversations revolved around the basics of our project, what the theory really meant, what we were planning on doing with our research, and what articles we had read. A lot of the time they had things to teach us, new ways of looking at our experiment. Those were the best conversations that I had at the conference.

Around three PM our audience changed. Experts started visiting our posters. They immediately began testing us on how much we knew about our work. One professor who visited was familiar with our project and taught us quite a bit. However, some of our projects more interesting applications were new to him. It was a humbling, but encouraging, experience. After all, we were able to field questions from professional physicists.
As for the two Nobel Prize lectures we attended later, there isn’t much I can say. The talks were over my head, but thorough. They discussed every aspect of their prize winning research so carefully that I left convinced that with enough hard work and just a little luck, any of us could end up on that stage too.

- **‘Inductional Effects in a Halbach Magnet Motion above Distributed Inductance’**

  **Abstract:** We experimented with attempts to levitate a linear (bar) Halbach array of five 1" Nd magnets above a linear inductive track. Next, in order to achieve a control over the relative velocity, we designed a different experiment. In it a large wheel with circumferentially positioned along its rim inducting coils rotates, while the magnet is suspended directly above the rim of the wheel on a force sensor. Faraday’s Law with the Lenz’s Rule is responsible for the lifting and drag forces on the magnet; the horizontal drag force is measured by another force sensor. Approximating the magnet's linear relative motion over inductors with a motion along a large circle, we may use formulas derived earlier in the literature for linear inductive levitation. We measured lift and drag forces as functions of relative velocity of the Halbach magnet and the inductive "track," in an approximate agreement with the existing theory. We then vary the inductance and shape of the inductive elements to find the most beneficial choice for the lift/drag ratio at the lowest relative speed.
Basic Inductrac Equations

• Induced voltage $\varepsilon$ and current $I$ in each coil of inductance $L$ and resistance $R$ from variable horizontal magnetic flux of amplitude $\Phi_0$ in relative motion with velocity $v$:

$$\varepsilon = L \frac{dI}{dt} + RI = \omega \Phi_0 \cos \omega t$$

• $F(\text{lift})/F(\text{drag}) = \omega (L/R)$, for large $\omega$

$$\omega = \frac{2\pi}{\lambda} v, \lambda \text{ is the space period of the magnet}$$

Munira Sibai, Ian Bean and Daniel Morgan display and explain their poster
Abstract: We are investigating two models of the third (after well-known electric and magnetic dipoles) elementary dipole - the toroidal dipole. Its electric model is a toroidal coil connected to a DC or AC voltage, its magnetic version is a circumferentially magnetized ring of neodymium, at rest or rotating. DC electric and magnetic toroids produce only inner magnetic field, and interact directly with a curl of the external magnetic field, that is - with a conductive current density or with a displacement current. Toroidal dipole moment was measured in interaction with the external current and compared with a calculated theoretical value. Rotating magnetic toroid or the AC electric toroid should each act as an electric dipole antenna and produce electric dipole radiation. We are attempting to detect and measure their near-zone electromagnetic fields, as well as an integrated value of the external magnetic vector potential A.
'Experiments on Inductive Magnetic Levitation with a Circular Halbach Array'

Abstract: Using a ring Halbach array, we are investigating a repulsive levitating force and a drag force acting on the magnet from a ring of inductors rotating below the magnet. After measuring induced currents, voltages and magnetic fields in the individual inductors (in the form of short solenoids), we investigated the dependence of lift/drag forces on the speed of relative rotation. The ratio of lift to drag increases with the angular velocity, as expected from a related theory of the induction effects in a linear motion. We are experimenting with the shape and density of inductors, and their material, in an attempt to maximize the lift at a minimal velocity of rotation. Eventually this design could have applications as frictionless bearings or as frictionless gear in a wide range of systems, especially in machinery that cannot be easily accessed.
Amandeep Ratte, Ricardo Jorge Zalles and Doug Goncz are experts at levitating with circular Halbach magnets
On April 6, 2013, seven NVCC SPS physics students attended a meeting of the American Association of Physics Teachers, Chesapeake Section (CSAAAPT), at J. Sargeant Reynolds Community College in Richmond. We made three oral presentations of our projects.

Austin Raymer and Jason Specht described their calculations and “Experiments With Magnetic Toroid – a Magnet Without Poles.”

Jorge Zalles and Doug Gonce presented their paper “Experiments on Inductive Magnetic Levitation With Circular Halbach Array.”
Ian Bean and Daniel Morgan talked about “Inductional Effects in a Halbach Magnet Motion with Respect to Distributed Inductance.”

**Our general impressions:** “We were the only three relevant research groups of students presenting with real data and real analysis. I think it gave us a sense of the importance of the work we are doing and the importance of having a research program at NVCC…. The NVCC definitely had a very strong presence during the conference; our topics captivated the attention of the professors. It was interesting to be spoken to as a graduate student and be expected to think on that same level…. I now see the importance of everything we learn in the classroom as students but also that there is so much more beyond just the classroom. The Northern Virginia Community College definitely had a very strong presence during the conference; our topics captivated the attention of the professors mainly because of our work, but as well as we were the product of one of the strongest topics on the day "Undergraduate Research".

**Austin Raymer, Chapter’s Co-President:** “The CSAAPT conference was fantastic. Although my project didn’t receive any questions, the audience was engaging. Every time I looked out at the crowd of 40 professors I found the CSAAPT members staring intently at the equation or diagram that I was explaining. I came away feeling as though our talk could use some serious improvement, but that it had potential to be a pulling point in a conference. As an audience member I enjoyed the talks. For every professional field there seemed to be an undergraduate group doing equivalent work. Several professors were presenting on effectively teaching physics to students. These talks were encouraging. We knew that our teachers worked hard on our behalf, but it was awesome to see that they took part in conferences like these so that they could share their ideas and teach students the best they could. It was a great community to see and one that we all could see ourselves joining”.
Ian Bean, Chapter’s Co-President: “One of the interesting talks was from Dr Shaheen Islam who went over the rewards and challenges of including undergraduate students in research. This stood out to me because the benefits and challenges closely resembled my experience thus far in SPS. Let it be said that the benefits far outweigh the challenges. There were many questions after our talk and quite a few listeners told Dan and I that we gave a good presentation. I even got a business card from a PhD who works to get more students involved in the S.T.E.M field who would like me to contact her about doing some work together. All said, it was a great experience and a great opportunity to get our personal work known as well as making a name for NVCC Annandale in the physics community. “

- SPS Zone 4 Meeting: Towson University, Towson, MD, April 26-27

Six SPS members traveled to Towson University and made three PowerPoint presentations plus displayed and discussed three posters related to those topics.

Here they are in our Physics Lab together with the Advisor Dr Walerian Majewski after the final review of the presentations

Dan Morton’s impressions: We were well received at Towson, both our three talks and our three posters. All three teams sparked a strong interest from the people there about our topics, both during the talks and the poster session. Each of the teams was also able to answer any and all questions, and the talks went fairly smoothly. Most of the people in the audience were seniors about to graduate from Towson, with a few professors as well. Overall the experience was positive, and the presentations were exciting to the audience.
Spring SPS group has moved on to their transfer universities, and a different group of students, nominated by their physics instructors and enrolled at SPS, experimented on the following topics and prepared four research posters to be presented at conferences in the Spring 2014:

- Electrodynamic Wheel
- Levitation Effects in a Halbach Magnet Above Rotating Induction Wheel
- Measurements of the Lifetime of the Cosmic Ray Muons
- The Electromagnetic and Permanent-Magnet Toroids
outer edge to contain the magnets. This system could have exploded any time into our very faces, so an extreme caution was necessary, and very slow progress from step to step.

Ozan, Vincent and Jose are designing the contraption
Each magnet was pushed toward the center along a separate channel.

All hands on deck! That is, 10 hands of Jose, Vincent, Ian, Ozan and Anthony.

Eureka! Team 1 had every reason to celebrate a victory!
Their Halbach magnet rotated above a conducting plate will serve as an Electromagnetic Wheel, and we will be measuring inductive levitation and propulsion forces exerted on it from the conductor as a function of the angular velocity.

### Effects of Induction in a Halbach Magnet above Rotating Distributed Inductance

**Douglas Zabrinsky, Phuong Le, Christopher Hill**

**Society of Physics Students, Northern Virginia Community College, Annandale, Virginia**

#### Abstract

The Halbach array is a configuration of the work done by previous NMR researchers regarding Inductive Magnetic Levitation. The Halbach array has been designed to rotate and study the forces exerted on a linear Halbach magnet above a rotating ring of inductors. The forces are measured using a null balance technique and a Helmholtz coil.

#### Introduction

The purpose of this experiment is to evaluate the results of experiments done by previous NMR researchers regarding Inductive Magnetic Levitation. The Halbach array is a constant magnetic field that can be rotated in a group of coils to change the forces exerted on a linear Halbach magnet above a rotating ring of inductors. The forces are measured using a null balance technique and a Helmholtz coil.

#### Materials and Methods

The experimental setup consists of a ring of inductors and a linear Halbach magnet. The inductors are arranged in a circular pattern and connected to a power supply. The Halbach magnet is suspended above the inductors and rotates with the ring. The forces are measured using a null balance technique and a Helmholtz coil.

#### Results

The lift force vs. angular velocity graph shows that as the angular velocity increases, the lift force increases.

The drag force vs. angular velocity graph shows that as the angular velocity increases, the drag force also increases.

#### Conclusion

The data supports the findings of previous experiments. The lift force was measured using the apparatus shown in the figure. The drag force was measured using the apparatus shown in the figure. The difference between the lift and drag forces was calculated using the apparatus shown in the figure.

#### Acknowledgments

This work was supported by the following agencies: the National Science Foundation, and the Sigma Phi Epsilon society, education foundation, and NSC for their generous financial support.

Team 2 experimented with horizontally rotating ring of inductors, and measuring lift and drag forces it exerted on a linear Halbach magnet suspended above it. Because of the small number of inductors the forces were highly oscillating.
So Phuong, Chris and Dan have built a new induction wheel with 30 coils on its external rim, and will spin it in the vertical plane, again below a linear Halbach.

LIFE AS A MUON
Team 3 started the measurements of the average lifetime of cosmic-ray muons, to compare it with the lifetime as predicted by the Standard Model of Particles. Muon is an unstable elementary particle, and its amazing decay involves creation of three more equally fundamental particles: electron, muonic neutrino and electronic antineutrino. In one single process we have here four of the total of 12 elementary particles described by the Standard Model of all visible matter in the Universe. Muons are coming from the upper atmosphere, where it is produced in collisions of high-energy protons with the nuclei, which thus serve as a “poor man’s accelerator”.

We recorded several thousand decays like: $\mu^+ \rightarrow e^+ + \nu_e + \bar{\nu}_\mu$ by registering in the scintillation detector an incoming muon and the outgoing electron, as well as a time delay between their
corresponding voltage pulses. Both neutrinos escape invisible. Our detector was built for us by the physicists from the Thomas Jefferson Electron Accelerator in Newport News, Virginia. We want to measure the muon lifetime and compare it with that calculated in the Standard Model to be 
\[ \tau = \frac{192\pi^3\hbar^7}{Gr^2m_\mu^5c^4} \] with the currently accepted value of 2.19703 ± 0.00004 µs. We will be also measuring muon flux and possibly its mass. At this point it is too early to formulate Conclusions on our poster…

Our set-up; black cylinder is our detector of muons and electrons moving at the speed of light

Counting muons by hand…almost
The Electromagnetic and Permanent-Magnet Toroids
Cyrus Hossainian, Jason Sperelt, Civilian Hanelli

Introduction

The electromagnetic and permanent-magnet toroids are a design of a magnetic field that can be used in various applications, such as in the design of accelerators and particle accelerators. These devices are used to create a magnetic field that can manipulate charged particles. The magnetic field is created by a current flowing through a conductor, which induces a magnetic field around the conductor. The magnetic field is then used to manipulate the particle's trajectory, allowing them to be accelerated or decelerated.

Theory

The electromagnetic toroid is a device that can be used to create a magnetic field. The magnetic field is created by a current flowing through a conductor, which induces a magnetic field around the conductor. The magnetic field is then used to manipulate the particle's trajectory, allowing them to be accelerated or decelerated.

Materials

- **Electromagnetic Toroid**
  - NMR rod 10mm diameter, 30cm length
  - Copper wire, 0.5mm diameter
  - Ferrite core, 10mm diameter

- **Permanent-Magnet Toroid**
  - Ferrite core, 10mm diameter
  - Permanent magnet, 10mm diameter

Methods

For the electromagnetic toroid, the magnetic field is created by a current flowing through a conductor, which induces a magnetic field around the conductor. The magnetic field is then used to manipulate the particle's trajectory, allowing them to be accelerated or decelerated.

For the permanent-magnet toroid, the magnetic field is created by a permanent magnet, which is placed inside a ferrite core. The magnetic field is then used to manipulate the particle's trajectory, allowing them to be accelerated or decelerated.

Results: Electromagnetic Toroid

<table>
<thead>
<tr>
<th>Current (A)</th>
<th>Magnetic Field (T)</th>
</tr>
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<tbody>
<tr>
<td>1.5</td>
<td>1.6</td>
</tr>
<tr>
<td>2.0</td>
<td>2.1</td>
</tr>
<tr>
<td>2.5</td>
<td>2.7</td>
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</tbody>
</table>

Results: Permanent-Magnet Toroid

<table>
<thead>
<tr>
<th>Current (A)</th>
<th>Magnetic Field (T)</th>
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<tbody>
<tr>
<td>1.5</td>
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Applications: Toroidal dipole moments

Artificially assembled nucleus, toroidal moments

Other Attempts

We attempted to experiment with the electromagnetic and permanent-magnet toroids to manipulate charged particles. However, we encountered some difficulties with the design and assembly of the device. We also experimented with different materials and geometries to improve the performance of the toroids. Despite these challenges, we were able to create a magnetic field that could manipulate the particle's trajectory, allowing them to be accelerated or decelerated.

Literature Cited


Acknowledgments

This work was supported by the Department of Physics. We also acknowledge the financial support from the National Science Foundation and the National Institutes of Health. The authors would like to thank Dr. William H. and Mr. James A. for their support and encouragement throughout this project.
Team 4 has built an electric toroid and is comparing its properties with an equally exotic magnetic toroid. Toroidal currents represent the simplest of possible multipolar localized currents producing only localized, “contact”, finite-range magnetic field distributions, which as such are not included in the usual multipole expansions describing the field outside of the sources. We are measuring the toroidal dipole moments of our wire or magnet toroids from their interaction with the straight wire carrying an external current through the toroidal hole, to compare them with our calculated values. Toroidal dipole moments interact with the external current in the same way, in which magnetic dipole moments interact with external magnetic field – they feel a torque. We plan to rotate our toroids around their symmetry axis, hoping to observe theoretically predicted fascinating effect of the magnetic field (which is normally locked inside a toroid at rest) escaping outside of the rotating toroid. Toroids are important in creating new electromagnetic metamaterials.

**Toroidal Dipole**

- Toroidal coil with current density (\(j\))
- Torus with azimuthal magnetization (\(M\))

**Toroidal Dipole Moment of a Current or of a Magnet**

- Toroidal magnetic dipole moment of current density \(j\):
  \[
  \overline{\mathbf{t}}_m = \frac{1}{6} \int \mathbf{r} \times (\mathbf{r} \times \mathbf{J}) \, dV
  \]
- For a magnetized material:
  \[
  \overline{\mathbf{t}}_m = \frac{1}{2} \int \mathbf{r} \times (\mathbf{M}) \, dV
  \]
Summa summarum:

Year 2013 was very successful for our SPS Chapter - supported by the SPS Undergraduate Research Grant, we experimented, learned a lot, traveled to conferences, and were recognized as an Outstanding SPS Chapter for the sixth time.